RECIPROCAL CROSS DIFFERENCES IN BRAHMAN-HEREFORD F_2 COWS: REPRODUCTIVE AND MATERNAL TRAITS

A Thesis

by

BRADLEY ALLEN WRIGHT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2006

Major Subject: Animal Breeding

RECIPROCAL CROSS DIFFERENCES IN BRAHMAN-HEREFORD F_2 COWS:

REPRODUCTIVE AND MATERNAL TRAITS

A Thesis

by

BRADLEY ALLEN WRIGHT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Chair of Committee,	James O. Sanders
Committee Members,	Andy D. Herring
	James E. Womack
Head of Department,	Gary Acuff

December 2006

Major Subject: Animal Breeding

ABSTRACT

Reciprocal Cross Differences in Brahman-Hereford F_2 Cows: Reproductive and Maternal Traits. (December 2006)

Bradley Allen Wright, B.S., Texas A&M University

Chair of Advisory Committee: Dr. James O. Sanders

Data from 75 F_2 Brahman-Hereford cows of four specific breed combinations, F_2 HB (produced by F_1 HB sires x F_1 HB dams, where "HB" refers to cattle sired by Hereford bulls and out of Brahman cows), F_2 BH (produced by F_1 BH sires x F_1 BH dams), HB x BH and BH x HB, were evaluated for maternal performance at the Texas A&M Research Center near McGregor. Differences between breed combinations were analyzed for calf crop born (CCB), calf crop weaned (CCW), calf survival (CS), birth weight (BW), weaning weight (WW), and cow weight at palpation (PW). The adjusted means for F_2 HB, F_2 BH, HB x BH, and BH x HB were 0.84 ± 0.06, 0.57 ± 0.07, 0.82 ± 0.06, and 0.62 ± 0.08, respectively, for CCW. F_2 HB cows had a 0.27 ± 0.09 higher percent calf crop weaned than F_2 BH cows ($P < 0.01$) and a 0.22 ± 0.11 higher percent calf crop weaned than BH x HB cows ($P < 0.05$). HB x BH cows had a 0.25 ± 0.08 higher percent calf crop weaned than F_2 BH ($P < 0.01$) and a 0.20 ± 0.10 higher percent calf crop weaned than BH x HB cows ($P < 0.05$). As 6-year-olds, the adjusted means for cow weight at palpation for F_2 HB, F_2 BH, HB x BH, and BH x HB cows were 523.65 ± 20.49 kg, 602.61 ± 23.63 kg, 492.84 ± 16.98 kg, and 515.93 ± 22.96 kg, respectively. Averaged across all ages, HB x BH cows weighed 56.59 ± 15.29 kg less than F_2 BH

cows ($P < 0.001$) and 41.11 ± 18.92 kg less than BH x HB cows ($P < 0.05$). Also, F_2 HB cows weighed 40.45 ± 17.68 kg less than F_2 BH cows ($P < 0.05$). In this herd, HB-sired cows had higher reproductive efficiency than BH-sired cows. Also, HB-sired cows tended to be lighter than BH-sired cows. Although these differences existed, exact causes could not be determined primarily due to confounding between the birth year of the cow and the sire breed of the cow.

ACKNOWLEDGMENTS

I would like to thank the many people that have supported me through the completion of this graduate program. I greatly appreciate the advice and direction offered to me by my advisory committee, Dr. Andy Herring and Dr. James Womack. I owe very much to the chair of my graduate committee, Dr. James Sanders. Dr. Sanders always believed in me, and his support and guidance are greatly appreciated. I would also like to thank Dr. Clare Gill for her advice and guidance throughout this endeavor. I greatly appreciate the help and friendship of the graduate students in the animal breeding and genetics section.

I especially owe a debt of gratitude to my wife Janeen. She spent many countless hours helping me and putting up with me when times were hard. I would also like to thank my parents, Jay and Diana Wright, for their love and support throughout all of my endeavors.

TABLE OF CONTENTS

LIST OF TABLES

Page

Page

Page

INTRODUCTION

Reproductive efficiency is the most important factor influencing the economy of beef production (Peacock et al., 1971; Cundiff et al., 1992). High production costs make it very important to achieve the highest weaning rate possible with the forage resources available (Peacock et al., 1971). Peacock et al. (1971) noted that reproductive performance is "the production trait most sensitive to nutrition, environmental conditions and adaptability of cattle to their environment." According to Long (1980), increasing the efficiency of beef production systems by genetic methods can be done primarily with selection within breeds to enhance critical characters, and by systematically combining breeds to produce individuals that better fit production conditions and resources. Comerford et al. (1987) noted that crossing divergent breeds is an effective way to improve the economically important traits of calving and weaning rate, birth weight, calving ease and 24-hr calf survival in beef cattle with the greatest amount of heterosis being seen for lowly heritable traits.

The problem with crossbreeding is that it is optimized with systems that are difficult to apply in small herds (Gregory and Cundiff, 1980; Gregory et al., 1991; Gregory et al., 1999). Ninety percent of the farmers and ranchers in the United States own 47.2% of the beef cattle in production units of 100 or fewer cows (Gregory et al., 1999; U.S.D.A., 2005). However, composite breeds can be managed as straightbreds, and the management problems that are associated with small herd size

---

This thesis follows the style and format of the Journal of Animal Science.

such as pasture availability, facilities, or the ability to maintain purebred herds used for crossbreeding can be avoided (Gregory and Cundiff, 1980; Gregory et al., 1999). With the use of composites, a producer can take advantage of additive breed differences to exploit desirable direct and maternal effects of specific breeds, as well as heterosis, while managing the herd as a single breeding population (Gregory et al., 1991; Newman et al., 1993; Gregory et al., 1999). The evaluation of performance of F_2 cows is integral to assisting farmers and ranchers that are attempting to utilize a desirable blend of breeds, as well as heterosis for direct and maternal effects, in a small herd.

LITERATURE REVIEW

The Brahman Breed

The American Brahman is the result of breeding various strains of Zebu males imported from India and Brazil to cows typical of the Gulf Coast region during the early 1900's (Sanders, 1980; Franke, 1980). Most of the Zebu cattle that have entered the United States have been of breeds that originated in India (Sanders, 1980). There are two distinctly different types of Brahman cattle; the Red Brahman and the Gray Brahman (Sanders, 1980). The Gray Brahman is primarily a mixture of Guzerat, as well as Nellore with some influence from other Zebu breeds, while the Red Brahman is primarily a mixture of Gir and Indu-Brazil, a breed developed in Brazil during the 1920's and 1930's, with some Guzerat influence. In both the Red and the Gray Brahman, there is a small influence from cows of the European breeds that were used in the grading up process (Sanders, 1980). The Indian breeds Guzerat, Nellore and Gir have had the most influence on Zebu cattle breeding in the United States. Purebred and grade Nellore females contributed to the American Brahman, although few pure Nellore bulls were used in the major Brahman herds after 1925 (Sanders, 1980).

Zebu cattle are uniquely suited to hot climates due to coat, hide, skin and hematological attributes (Turner, 1980). Heat tolerance in the Zebu can be attributed to their smooth-coat and better developed sweat and sebaceous glands than *Bos taurus* cattle, which allows them to lose more moisture by evaporation (Turner, 1980). Frisch and Vercoe (1978) listed Brahmans as resistant to ticks, worms, pinkeye, heat and nutritional fluctuations. Brahmans were also cited as having lower inherent voluntary feed intake and lower relative maintenance requirements (Turner, 1980). Brahman cows were observed to have a lower reproductive rate than Angus and Hereford cows in some studies (Cartwright et al., 1964; Crockett et al., 1978), but were superior to Shorthorn cows in other studies (Peacock et al., 1971). Compared with *Bos taurus* cattle in temperate environments, straightbred Zebu cattle are lower in reproduction, later maturing, slower growing and lower in beef quality. However, Zebu cattle are valuable in crossbreeding, due to increased adaptation to certain climatic conditions, along with large amounts of heterosis for growth, maternal effects and reproductive traits (Turner, 1980) and, consequently, have made a significant contribution to the cattle industry in the South and Southeastern United States (Franke, 1980).

The Hereford Breed

The Hereford breed is a British *Bos taurus* breed that was developed from the cattle of Herefordshire, England. The breed was developed on the basis of high yield and efficiency of production. Herefords first came to the United States in 1817, but these cattle had little effect on current Herefords. The first breeding herd in the United States was established in 1840 in Albany, New York. The ability of the Hereford to adapt and survive while greatly improving beef quality when mated to Spanish longhorned cattle created a huge demand for Hereford bulls. The importations of the 1870's and 1880's had the largest influence on modern Hereford cattle including the importation of Anxiety 4th in 1881 who is nicknamed the "Father of the American Herefords." Hereford influenced cattle also became desirable for the traits familiar to the British *Bos taurus* breeds. They are early maturing and fatten quicker than the cattle that were in the United States prior to 1880. This was seen in 1907 when a Hereford steer became the first steer less than two years of age to win the International Livestock Exposition (Oklahoma State University Website). Hammack (2003) stated that British breeds can be used for general-purpose production and are the “foundation of the U.S. beef herd.” Hammack (2003) also reported that Hereford cattle are moderate for most traits, including body size, hot climate adaptability, muscle expression and marbling, while being high in fleshing ability and low in milking potential. However, Cundiff (2006) reported results from the Germplasm Evaluation study (Cycle VII) that indicate that there is no significant differences between British and Continental European breeds for average cow weight or height at 5 years of age.

Crossbreeding

Willham (1970) described crossbreeding as “a management technique widely used by commercial beef producers attempting to improve production efficiency.” Willham (1970) also reported that crossbreeding utilizes heterosis, allows for rapid incorporation of desirable genetic material, and provides the opportunity for blending desirable characteristics in a market animal. Successful and effective crossbreeding requires the choice of appropriate breed combinations for the environment and production management system, as well as the exploitation of those breed effects and heterosis (Gregory and Cundiff, 1980; Koger, 1980; Roberson et al., 1986). Koger (1980) reported that effective crossbreeding aims to maximize weaning rate and maternal ability in the cow, and growth potential in the calf. Also, crossbreeding can utilize complementarity in part of a cow herd through the use of terminal sire breeds that have greater additive genetic merit for growth rate and/or carcass merit than the cow herd. Another application for crossbreeding, as mentioned previously, is to form new composite breeds from a multi-breed foundation with the objective of developing a breed that can take advantage of a desirable blend of breed characteristics and of heterosis, but still be managed as a straightbred (Gregory and Cundiff, 1980).

The challenge with crossbreeding is to maximize efficiency of production, as well as meet market requirements with available resources and management options, through the choice of germ plasm, mating systems, and methods of selection (Cundiff, 1977). Experiments with cattle of European origin have indicated that weight of calf weaned per breeding female exposed to a bull can be increased up to 23% through the use of systematic crossing (Cundiff et al., 1974a,b; Long, 1980; Bailey et al., 1990).

Matings of Zebu breeds with European cattle in the southern United States have shown even greater advantages in productivity than crosses between *Bos taurus* breeds due to the adaptability of the Zebu breeds to the hot and humid climate of the region and to the higher levels of hybrid vigor between Zebu and European breeds than in pairs of European breeds (Franke, 1980; Koger, 1980; Bailey et al., 1990). Zebu breeds, specifically the Brahman and Brahman crosses, have been used extensively in the Gulf Coast region because of their availability and well documented adaptability (Turner et al., 1968; Turner and McDonald, 1969; Peacock et al., 1971; Franke, 1980; Turner, 1980; Peacock et al., 1981). Koger noted in 1980 that commercial producers were expressing increasing interest in Brahman crosses because of the crosses' reputation for good maternal performance over a wide range of conditions. Much of the interest in

Brahman cattle is due to the noted differences between Zebu and European cattle which include variation in heat and cold tolerance; reproduction, parturition and lactation; growth and maturation rates; temperament and intelligence; and combining ability (Cartwright, 1980). This excellent reproductive and maternal performance of the Brahman x British cross female has been well documented (Baker and Black, 1950; Damon et al., 1959; Cartwright et al., 1964; Riley et al., 2001) and has led to the utilization of Zebu cattle in crossbreeding programs to take advantage of adaptation to hot climates and poor forage areas via additive inheritance and heterosis for reproductive, maternal and growth-related traits (Turner, 1980).

Heterosis

Heterosis influences most of the economic traits important to beef cattle production (Cartwright et al., 1964; Gregory et al., 1965; 1966a,b,c; Wiltbank et al., 1966; 1967; Klosterman et al., 1968; Pahnish et al., 1969; Hedrick et al., 1970; Lasley et al., 1971; Cundiff et al., 1974a,b; Long and Gregory, 1974; Urick et al., 1974; Willham, 1974; Gregory et al., 1978). Results indicated that advantages could be accrued through increased production of crossbred cows when compared with straightbred cows (Cundiff, 1977). In an experiment initiated in 1957 at Fort Robinson by Gregory et al. (1965), results indicated that production in terms of weaning weight per cow exposed could be increased 23% as a result of heterosis on survival and growth rate of crossbred calves and on increased fertility and milk production of crossbred cows (Gregory et al., 1965; Wiltbank et al., 1967; Cundiff et al., 1974a,b; Cundiff, 1977). Several studies have shown that weaning weight per cow exposed could be increased 50% or more for crosses between *Bos taurus* and *Bos indicus* breeds of cattle (Cartwright et al., 1964; Koger et al., 1975; Gregory and Cundiff, 1980). McCarter et al. (1991) illustrated that Brahman-cross dams could be used effectively in a commercial crossbreeding system to increase reproductive rate and preweaning growth rate compared with *Bos taurus*-cross dams because of increased maternal ability. Gregory and Cundiff (1980) showed that 60% or more of the observed cumulative heterosis was due to heterosis effects on maternal characters. This means that crossbreeding systems that are organized to use crossbred females are generally favored.

F_1 Reciprocal Cross Differences

Long (1980) reviewed many studies and reported that average reciprocal differences ranged from 1 to 11% (mean = 6%) for calving rate; from 1 to 3% (mean 2%) for calf survival at birth, and from 3 to 6% (mean = 4%) for calf survival to weaning. Long (1980) also reported that average reciprocal differences from 1 to 6% (mean = 3%) were found for calf weaning weight. Dearborn et al. (1987) found that Red Poll, Brown Swiss, Hereford and Angus differed in breed grandmaternal effects for percent of live calves born, percent of calves weaned, and 200-day weight. Specifically, progeny with Red Poll maternal grandams exhibited a higher live calf born and weaned percentage than progeny with Hereford maternal grandams while progeny with Hereford maternal grandams were heavier at 200 days than progeny with Red Poll maternal grandams. Cundiff et al. (1992) reported that grandmaternal effects on weaning rate tended to favor Hereford grandams over Angus and Shorthorn. Cundiff et al. (1992) also reported that Hereford grandmaternal effects, compared to Angus and Shorthorn, increased the number of calves weaned through 12 years of age. Gaines et al. (1978) reported that Angus x Hereford (where the first breed listed refers to the breed of sire) cows gave birth to 3.6% more calves than Hereford x Angus cows; Shorthorn x Hereford exceeded Hereford x Shorthorn by 6.0%, and Angus x Shorthorn exceeded Shorthorn x Angus by 5.7%. In contrast, Turner et al. (1968) found that when reciprocal crossbreds of Brahman and Hereford were compared, no significant differences in percent calf crop born or weaned were observed. Cundiff et al. (1974a) reported significant differences in reproduction between Hereford x Angus reciprocal crosses. They found that females out of Hereford dams exceeded the reciprocal cross in measures of percentage calf crop born and weaned. Significant differences favoring Angus x Hereford over Hereford x Angus cows were also found for pregnancy rate and weight of calf per cow exposed. A trend also favoring Hereford maternal grandams over Shorthorn maternal grandams was evidenced in Hereford-Shorthorn reciprocal crosses for measures of percentage calf crop born and weaned. Reciprocal differences between Angus x Shorthorn and Shorthorn x Angus cows were small in this study, and differences in post-natal survival were generally small and not significant based on all cows calving (Cundiff et al., 1974a). Cundiff et al. (1974a) also reported, in a separate analysis within management regime, that these differences were similar in both management systems. Cundiff et al. (1974a) also observed that Hereford x Angus females were heavier at weaning, heavier and carried more condition at maturity but produced less milk and were poorer in reproduction than Angus x Hereford females. Gaines et al. (1978) pooled sexes and compared reciprocal crosses to show that calves out of Angus x Hereford cows were

12.7 kg heavier than those from Hereford x Angus cows; calves out of Shorthorn x Hereford cows were 18.8 kg heavier than those from Hereford x Shorthorn cows; and calves out of Shorthorn x Angus cows were 6.5 kg heavier than those from Angus x Shorthorn cows. These results corresponded closely to results reported by Cundiff et al. (1974a,b). However, McDonald and Turner (1972) reported no significant differences in maternal heterosis for reciprocal crossbred cows for birth weight and weaning weight. Cundiff et al. (1974a) also reported that Angus x Hereford (with sire breed listed first) dams exceeded measures of Hereford x Angus dams by 7.7% for full-term calves born and 11.1% for calves weaned. The authors stated that the potential effect of maternal grandams was the most likely cause of reciprocal differences in this study (Cundiff et al., 1974a). Differences between Hereford-Shorthorn and Shorthorn-Angus reciprocal crosses were not significant for preweaning growth traits but they did tend to favor crossbred cows out of Hereford dams. Also, milk production at about 14 weeks postpartum was significantly greater in Shorthorn x Hereford cows than in Hereford x Shorthorn cows. Differences between Angus-Shorthorn reciprocal crosses were not significant for preweaning growth traits or milk production (Cundiff et al., 1974b).

In a previous phase of the current study, Key (2004) reported that, averaged across all ages, Hereford (H)-Brahman (B) (with sire breed listed first) dams had a slightly higher percent calf crop born than BH dams. Also, HB dams had a higher rate of calf survival, as well as a higher percent calf crop weaned than BH dams. In that study, unadjusted means showed little difference between BH and HB dams for birth or weaning weight of their calves.

F_2 Performance and Reciprocal Cross Differences

All Brahman crossbred cows take advantage of the maternal attributes of the Brahman and, if hybrid vigor is proportional to degree of heterozygosity, should retain some degree of hybrid vigor. If hybrid vigor is retained, crosses other than the F_1 have some fraction, depending on the cross, of the hybrid vigor of the F_1. Meaning that, if heterosis is retained, these subsequent crosses will exhibit higher performance than the average of the two purebreds, but be less productive than the F_1. The cost of producing and maintaining these additional crosses compared to their performance will be the driving force behind the merit of crosses other than the F_1 (Sanders, 1980). Seifert and Kennedy (1972), Seebeck (1973), Rendel (1980), and Mackinnon et al. (1989) all noted that very little heterosis was maintained in subsequent interbred generations of Brahman crosses. In that herd, Seebeck (1973) reported that F_2 Brahman cross cows had a 20.5% lower calving rate than that of the F_1.

In an earlier phase of the current study, Key (2004) reported lower heterosis in F_2 Brahman-Angus crosses than would be expected if heterosis were proportional to the degree of heterozygosity, but higher degrees of heterosis than expected in F_2 Brahman-Hereford cross cows. In that study, Key (2004) reported large differences in calf crop born and calf crop weaned, as well as differences in 4-years-of-age cow weight. The author reported least squares means for calf crop born for the cow breeds F_2 HB (produced by Hereford-sired F_1 bulls mated to Hereford-sired F_1 cows), F_2 BH (produced by Brahman-sired F_1 bulls mated to Brahman-sired F_1 cows), BH x HB (produced by Brahman-sired F_1 bulls mated to Hereford-sired F_1 cows), and HB x BH (produced by

Hereford-sired F_1 bulls mated to Brahman-sired F_1 cows) of .98, .69, .79, and .97, respectively. Least squares means for calf crop weaned were .91, .61, .75, and .92 for F_2 HB, F_2 BH, BH x HB, and HB x BH, respectively. For calf survival, least squares means of .92, .88, .93, and .94 were reported for calves out of F_2 HB, F_2 BH, BH x HB, and HB x BH cows, respectively. The author also reported least squares means for cow weight at 4 years of age of 464.5 kg, 551.0 kg, 506.8 kg, and 495.3 kg for the cow breeds F_2 HB, F_2 BH, BH x HB, and HB x BH, respectively. These apparent differences between specific breed combinations of F_2 Brahman-Hereford crosses are the basis of the current study. Also in that study (Key, 2004), F_2 Angus (A)-Brahman (B) cows by AB (with sire breed listed first) sires had a higher percent calf crop born than BA-sired cows. AB-sired cows also had a higher percent calf crop weaned than BA sired cows further illustrating the apparent negative influence of the Brahman paternal grandsire on reproductive efficiency.

In a Florida study, F_2 Brahman-Angus cows exhibited pregnancy rates slightly below what would be expected based on their degree of heterozygosity, while F_2 Brahman-Charolais cows had higher pregnancy rates than would be expected based on their degree of heterozygosity (Olson et al., 1993; T.A. Olson, personal communication). In that same study, calves out of F_2 Brahman-Angus cows had a survival rate of 92.4 percent which is similar to what was expected based on their degree of heterozygosity, while calves out of F_2 Brahman-Charolais cows had lower survival rates (88.6%) than those out of the parental breeds (89.1% and 95.2% for those out of Brahman and Charolais cows). With a combination of pregnancy rates and calf survival, calf crop weaned percentages of the F_2 cows was at least as high as expected based on the degree of heterozygosity. In the Olson et al. (1993) study, however, the authors did not evaluate differences between reciprocal crosses.

Rendel (1980) reported that Brahman-cross cows in the F_2 generation had a calving rate that was almost as low as the calving rate of the purebred Brahman, even though they retained the favorable blend of breed characteristics seen in the F_1. The author suggested that the low calving rate of crosses descending from the mating of *Bos taurus* cows and Brahman bulls in the F_2 and following generations, as well as in breeds derived from the cross, could be due to the difference between the *Bos taurus* Y chromosome and the *Bos indicus* Y chromosome if this difference was due to a translocation between the Y and an autosome or an X chromosome. It was also suggested that such a translocation could set up a balanced polymorphism which could lead to lower calving rates in the F_2 and subsequent generations. For the purposes of the hypothesis, it was not necessary that there be a translocation from the Y to another chromosome. The reverse would have the same result as long as some relationship existed between the Y and another chromosome in the genome, which resulted in low calving rates and interactions between chromosomes in crosses (Rendel, 1980). Rendel (1980) acknowledged that in that study, low calving rates in the F_2 compared to the F_1 could not be explained by a deficient Y chromosome since both generations of males carried the same Y. However, if the crossbreds were derived from a Brahman male so that the Y always came from the Brahman, a translocation from the Y to another chromosome could, under the right conditions, set up a stable polymorphism, which would cause low calving rates in the population, even though some individual animals would have high fertility. Rendel (1980) also noted that there was no cytological evidence of such a translocation to date.

Mackinnon et al. (1989) reported that reciprocal crossing of the Africander-cross (AX) and Brahman-cross (BX) lines generated 6% heterosis in the F_1 AXBX, and all of this was maintained in subsequent generations. Mackinnon et al. (1989) stated that if Rendel's (1980) hypothesis were true, all breeds derived from *Bos indicus* x *Bos taurus* crosses, in which the parent bulls had the *Bos indicus* Y chromosome, would be lower in fertility. Accordingly, reciprocal matings between AX and BX were made to test this hypothesis, and it was reported that in the F_2 and following generations of the AXBX, the line of animals carrying the *Bos indicus* Y chromosome had similar fertility to the line carrying the *Bos taurus* Y chromosome. Therefore, the data from this study did not support Rendel's (1980) hypothesis (Mackinnon et al., 1989). However, the comparison included mainly F_2 and some F_3 animals, which could lead to the presence of some linkage disequilibrium, possibly masking the effect of any translocation. Nevertheless, there was no evidence of any effect on fertility associated with the *Bos indicus* Y chromosome (Mackinnon et al., 1989). Reciprocal differences between F_1 dams have been well documented (Cundiff et al., 1974a,b; Marshall et al., 1976; Gaines et al., 1978; Long, 1980; Dearborn et al., 1987; Cundiff et al., 1992), as well as the lack of reciprocal differences in some studies (Turner, 1968; McDonald and Turner, 1972), but there have apparently been no studies in the United States evaluating the differences of reciprocally produced F_2 females.

Models

Dickerson (1969) and Willham (1972) have shown that reciprocal cross dams are expected to be equal in terms of all genetic components except for an effect due to maternal grandams expressed through interaction with subsequent maternal ability. The authors illustrated this based on models, assumed to be correct, including adjustments for direct and maternal heterosis of an individual, its dam, and its maternal grandam, as well as non-allelic gene interactions to account for recombination in F_2 individuals and the effect of non-allelic gene interactions on maternal environment and grandmaternal effects. Dickerson (1969) acknowledged the possibility of deviations due to sex-linked effects, but cited Damon et al. (1961) in stating that these effects are likely to be negligible for economic traits in livestock and were ignored in this study. Cundiff et al. (1974b) illustrated that the interaction between maternal grandam and her daughters' subsequent productivity could result if heifers that had heavy weaning weights because of favorable maternal environment provided a poorer maternal environment and produced lighter calves at weaning in the subsequent generation. In comparisons of breeding programs, Dickerson (1969) used a model that included a term for the effects of genotype for maternal grandams, through modification of direct maternal effects. In F_1 calves of a four breed diallel of Red Poll, Brown Swiss, Angus and Hereford, Gregory et al. (1978) found that breed of sire, breed of dam, year, age of dam, and sex of calf had important effects on most of the traits evaluated. The authors specifically observed significant breed of sire effects for all traits except perinatal mortality and calf crop weaned. The year-age of dam main effect was a significant source of variation for all preweaning traits analyzed. Year and age of dam effects on preweaning traits have been found to be important at other locations as well (Gregory et al., 1965; Sagebiel et al., 1969; Turner and McDonald, 1969; Long and Gregory, 1974).

In a study of Brahman, Hereford, reciprocal F_1 crosses and backcrosses, Roberson et al. (1986) found that birth weight increased with dam age up to 7 years of age and then declined gradually for older dams, while weaning weight least-squares means increased with dam age for up to 9-year-old dams. Large differences in birth weights were also associated with year effects. For preweaning gain and weaning weight, both year and age of dam apparently contributed to the variation (Roberson et al., 1986). Long and Gregory (1974) described year effects as values that were presented as a sample of possible differences which may have occurred due to weather, forage availability, management and other factors which may vary with year. Mangus and Brinks (1971) studied inbred lines of Hereford cattle in Colorado and observed that the year in which the cow was born had an effect upon her subsequent productivity. The authors showed that cow birth year is expected to be an environmental factor affecting cow productivity because year effect reflects the nutritional level available to the heifer calf and her dam during the preweaning growth period. In addition to cow birth year, Mangus and Brinks (1971) also listed age of dam and the cow's weaning weight as factors which reflected the preweaning levels of nutrition and which had a significant effect upon future producing ability.

Peacock et al. (1971) reported that survival rate was significantly influenced by year effects and sire breed of calf in several different Brahman-Shorthorn crosses. The authors also found that sire breed of calf effects were highly significant for pregnancy rate but approximately nonexistent for weaning rate. This resulted from breed effects being reversed for pregnancy and survival rates. McCarter et al. (1991) reported that breed composition of the calf's dam affected preweaning average daily gain, weaning weight, conformation, condition and height. Given the scarcity of information on reciprocal differences within the F_2 generation, F_2 *Bos indicus* x *Bos taurus* cross cows need to be sufficiently analyzed under United States conditions to consider the merit of producing and utilizing F_2 females and females resulting from subsequent generations of *inter se* mating.

OBJECTIVE

The objective of this study is to evaluate the reproductive and maternal performance of the four types of reciprocal F_2 Brahman (B)-Hereford (H) crosses. These four types of cows are: F_2 HB (produced by Hereford-sired F_1 bulls mated to Hereford-sired F_1 cows), F_2 BH (produced by Brahman-sired F_1 bulls mated to Brahman-sired F_1 cows), BH x HB (produced by Brahman-sired F_1 bulls mated to Hereford-sired F_1 cows), and HB x BH (produced by Hereford-sired F_1 bulls mated to Brahman-sired F_1 cows).

MATERIALS AND METHODS

Description of Data

Data from 75 F_2 Brahman-Hereford cows of four specific breed types, F_2 HB, F_2 BH, BH x HB, and HB x BH, at the Texas A&M Research Center at McGregor were evaluated for maternal performance as part of Texas Agricultural Experiment Station Project H6883. All of the cows in the study were produced by natural service at the McGregor Research Center, and were born from 1996 to 1999. The F_1 BH sires used to produce these cows were raised at the McGregor Research Center, while the F_1 HB sires were purchased from breeders in Texas. In addition to these cows, 53 cows composed of one-quarter each of Brahman (B), Nellore (N), Hereford (H) and Angus (A) born from 1996 to 2001 were evaluated to assist in the resolution of confounding problems between the birth year of the cow and the sire breed of cow. Three specific breed types of this quarter-blood composite were evaluated; BA x NH (with sire breed listed first, produced by a B x A sire mated to a N x H dam), NA x BH (produced by a N x A sire mated to a B x H dam), and NA x HB (produced by a N x A sire mated to a H x B dam). Table 1 shows the number of cows in each breed type and the years in which they were born.

Cows and heifers were bred to have spring calves in multiple sire-pastures. Heifers were bred to calve as two-year-olds. In the F_2 Brahman-Hereford herd, F_2 HB and HB x BH heifers were bred to F_1 Brahman x Hereford bulls during the 1998 breeding season. From 1999 to 2005, all cows were bred to F_1 Nellore x Angus bulls. With the exception of 2000 and 2001, heifers were also bred to F_1 Nellore x Angus bulls. In 2000, heifers were bred to ¾ Angus ¼ Nellore bulls, and in 2001, heifers were bred to

Angus bulls. The four breed quarter-blood composites were bred to Brangus and ¾ Angus ¼ Nellore bulls in most years. Most of the heifers were bred to Angus bulls although, in some years, heifers were bred to Brangus and, in other years, to ¾ Angus ¼ Nellore bulls. There were also some calves born to these cows that were sired by a Charolais bull that got in the pasture. Table 2 lists the breeds of sires used on the various breed types.

With the exception of three early born calves in 2002, calving occurred between February 9 and May 13 of each year. Calves are weighed and tagged within 12 hours of birth when possible. The calves are weaned at approximately seven months of age in October or November of each year. At this time, weaning weights were taken, as well as each calf being assigned a body condition score. Also at this time, cows were weighed, palpated for pregnancy determination and given a body condition score. Cows in this study were culled after their second failure to wean a calf. In some cases during this study, cows were culled for other reasons and palpation status was used to determine the following year's data. For example, if a cow was culled after being palpated open, she was recorded as failing to calve in the following year; however, if she was palpated bred no record was reported for the following year because she was not given the opportunity to have and raise a calf.

Table 1. Number of cows by cow breed[a] and birth year

	Birth Years						
Cow Breed	1996	1997	1998	1999	2000	2001	Total
F_2 HB[b,c]	3	4	-	8	-	-	15
F_2 BH	-	15	8	-	-	-	23
HB x BH[d]	9	10	-	5	-	-	24
BH x HB	-	3	10	-	-	-	13
NA x BH	-	-	-	5	16	4	25
NA x HB	-	-	-	-	2	4	6
BA x NH	7	-	7	6	2	-	22
Total	19	32	25	24	20	8	128

[a]A – Angus, B – Brahman, H – Hereford, N – Nellore
[b]Both parents were from the same crossbred group.
[c]Pairs of letters indicate a crossbred group with sire breed listed first and dam breed listed second.
[d]First pair of letters designates crossbred sire. Second pair of letters designates crossbred dam.

Table 2. Breeds of bulls exposed to cow breeds

Cow Breed	Breeds of Bulls
F_2 HB	A, BH, NA
F_2 BH	NA, 3/4 A 1/4 N
HB x BH	A, BH, NA
BH x HB	NA, 3/4 A 1/4 N
NA x BH	A, C[a], Bn[b], 3/4 A 1/4 N
NA x HB	A, C, Bn, 3/4 A 1/4 N
BA x NH	A, C, Bn, 3/4 A 1/4 N

[a]C - Charolais
[b]Bn - Brangus

Traits Analyzed

Cow reproduction was evaluated in terms of percentage calf crop born, calf crop weaned and calf survival. Calf crop born was measured as the percentage of cows exposed during the breeding season that calved during the following spring. Calf crop weaned was measured as the percentage of cows exposed during the breeding season that weaned a calf in the fall of the following year. Calf survival was represented as the percentage of calves born, either alive or dead, that survived to weaning. These traits were analyzed as binary traits, with zero representing a failure and one indicating a success for a given trait. Table 3 illustrates the number of observations for each of these traits by cow breed.

Birth weight and weaning weight of the calves out of these cows were also analyzed. Birth weights were recorded soon after birth, and weaning weights were measured at approximately seven months of age. In the fall, at the time of weaning, cows were weighed and palpated. The numbers of observations for birth weight, weaning weight, and cow weight across all ages are reported in Table 4 by cow breed.

Table 3. Number of observations for reproductive traits within each cow breed

Cow Breed	Calf Crop Born	Calf Crop Weaned	Calf Survival
F_2 HB	77	67	57
F_2 BH	63	60	36
HB x BH	100	92	75
BH x HB	60	57	40
NA x BH	111	91	78
NA x HB	24	20	19
BA x NH	112	103	88
Total	547	490	393

Table 4. Number of observations for calf and cow weight traits within each cow breed

Cow Breed	Calf Birth Weight	Calf Weaning Weight	Cow Weight
F_2 HB	65	55	78
F_2 BH	38	30	76
HB x BH	82	70	110
BH x HB	43	36	61
NA x BH	95	70	91
NA x HB	21	16	19
BA x NH	95	72	94
Total	439	349	529

Statistical Analysis

Cow Reproductive Traits

The traits previously discussed were analyzed by the MIXED model procedure of SAS version 9.1 (SAS, 1990). Least square means were calculated for each of these traits as dependent variables. Calf crop born, calf crop weaned, and calf survival were analyzed with the fixed effects of sire breed of cow, dam breed of cow, the interaction between sire breed and dam breed of the cow, and year of record combined with age of cow. Year of record combined with age of cow was used to increase the degrees of freedom available for analysis over that of a model containing age of cow and year of record or birth year of cow and year of record. Also, with the exception of cows born in 1997, sire breed of cow is at least partially confounded with the birth year of the cow. Cow within breed was used as a random effect in the model. These traits were also analyzed across cow ages with fixed effects of breed of cow, year of record, age of dam and the interaction between breed of cow and age of cow included, as well as the random effect of cow within breed. The traits were then analyzed across cow birth years with the fixed effects of breed of cow, year of record, birth year of the cow, and the interaction between the breed of cow and the birth year of the cow. This model also included cow within breed as a random effect.

Weight Traits

Birth weight was analyzed in the same manner as the reproductive traits with the addition of fixed effects for sire breed of calf and sex of calf. Weaning weight was also analyzed in the same manner as the reproductive traits with the addition of weaning age of calf and sex of calf as independent variables. As with the reproductive traits, both models contained cow within breed as a random effect. Cow weight at palpation was analyzed for the Brahman-Hereford crosses across all ages with 8-years-of-age being the oldest age in which at least one cow from each breed type was evaluated. For purposes of discussion six-years-of-age will be considered the age at which these cows reached maturity because the imposed culling policy reduces numbers rapidly after that point, and also, a large number of F_2 HB and HB x BH cows were born in 1999 and data only exists on these cows through 6-years-of-age. Also, trends in the averages across cow breeds within years show that the mature weight of these cows was reached at 6-years-of-age. The model for analyzing cow weight was the same as that for the reproductive traits. As in the other models, cow within breed was included as a random effect.

RESULTS AND DISSCUSSION

Calf Crop Born

Unadjusted means by cow breed and age are presented in Table 5, while unadjusted means by cow breed and birth year are presented in Table 6. Among the Brahman-Hereford crosses, the F_2 BH cows had the lowest percent calf crop born as 2-year-olds, as well as across all ages. The F_2 HB cows had the highest percent calf crop born as both 2-year-olds and across all ages.

Adjusted means for calf crop born by cow breed are presented in Table 7. Adjusted means by cow breed and age are presented in Table 8, and adjusted means by cow breed and birth year are presented in Table 9. The adjusted means for F_2 HB, F_2 BH, HB x BH, and BH x HB cows were 0.87 ± 0.05, 0.74 ± 0.06, 0.88 ± 0.05, and 0.83 ± 0.07, respectively. Only the fixed effect of year of record combined with age of cow had a significant effect on calf crop born ($P < 0.001$). Differences between adjusted means of percent calf crop born by breed of cow are presented in Table 10. Even though no significant difference was found in the analysis of variance for the fixed effect of sire breed of cow ($P > 0.10$) or the interaction between sire breed of cow with dam breed of cow ($P > 0.25$), F_2 BH cows had a 0.14 ± 0.07 lower percent calf crop born than HB x BH cows ($P < 0.05$). F_2 BH cows also had a 0.13 ± 0.08 lower percent calf crop born than F_2 HB cows ($P < 0.10$).

Table 5. Unadjusted means, standard deviations, and numbers of observations for calf crop born by breed and age of cow

	Age									
Breed	2	3	4	5	6	7	8	9	10	Total
F_2 HB	0.87	0.64	0.92	1.0	0.91	0.90	0.50	1.0	0.0	0.84
	(0.35)	(0.50)	(0.29)	(0.0)	(0.30)	(0.32)	(0.71)	(-)	(-)	(0.37)
	15	14	12	11	11	10	2	1	1	77
F_2 BH	0.40	0.64	0.55	0.67	1.0	1.0	1.0	1.0	-	0.62
	(0.50)	(0.50)	(0.52)	(0.52)	(0.0)	(0.0)	(0.0)	(0.0)		(0.49)
	20	14	11	6	4	3	3	2		63
HB x BH	0.70	0.57	0.92	1.0	1.0	0.90	1.0	1.0	1.0	0.82
	(0.47)	(0.51)	(0.29)	(0.0)	(0.0)	(0.32)	(0.0)	(0.0)	(0.0)	(0.39)
	23	21	12	12	11	10	4	4	3	100
BH x HB	0.62	0.33	0.89	1.0	0.88	0.67	1.0	-	-	0.72
	(0.51)	(0.49)	(0.33)	(0.0)	(0.35)	(0.52)	(0.0)			(0.45)
	13	12	9	8	8	6	4			60
NA x BH	0.80	0.79	0.90	0.95	0.88	0.67	-	-	-	0.86
	(0.41)	(0.41)	(0.30)	(0.22)	(0.33)	(0.58)				(0.35)
	25	24	21	21	17	3				111
NA x HB	1.0	1.0	0.83	1.0	0.50	-	-	-	-	0.92
	(0.0)	(0.0)	(0.41)	(0.0)	(0.71)					(0.28)
	6	6	6	4	2					24
BA x NH	0.86	0.68	0.95	0.89	0.92	0.89	0.60	1.00	1.00	0.85
	(0.35)	(0.48)	(0.23)	(0.32)	(0.29)	(0.33)	(0.55)	(0.0)	(0.0)	(0.36)
	22	22	19	19	12	9	5	2	2	112
Total	0.73	0.65	0.87	0.94	0.91	0.85	0.83	1.0	0.83	0.81
	(0.45)	(0.48)	(0.34)	(0.24)	(0.29)	(0.36)	(0.38)	(0.0)	(0.41)	(0.40)
	124	113	90	81	65	41	18	9	6	547

Table 6. Unadjusted means, standard deviations, and numbers of observations for calf crop born by breed and birth year of cow

	Birth Year						
Breed	1996	1997	1998	1999	2000	2001	Total
F_2 HB	0.78	0.75	-	0.91	-	-	0.84
	(0.43)	(0.45)		(0.29)			(0.37)
	18	16		43			77
F_2 BH	-	0.63	0.60	-	-	-	0.62
		(0.49)	(0.51)				(0.49)
		48	15				63
HB x BH	0.80	0.75	-	0.96	-	-	0.82
	(0.41)	(0.44)		(0.20)			(0.39)
	40	36		24			100
BH x HB	-	0.80	0.70	-	-	-	0.72
		(0.42)	(0.46)				(0.45)
		10	50				60
NA x BH	-	-	-	0.77	0.87	0.92	0.86
				(0.43)	(0.34)	(0.28)	(0.35)
				22	76	13	111
NA x HB	-	-	-	-	0.90	0.93	0.92
					(0.32)	(0.27)	(0.28)
					10	14	24
BA x NH	0.85	-	0.81	0.87	0.90	-	0.85
	(0.36)		(0.40)	(0.35)	(0.32)		(0.36)
	41		31	30	10		112
Total	0.82	0.70	0.72	0.88	0.88	0.93	0.81
	(0.39)	(0.46)	(0.45)	(0.32)	(0.33)	(0.27)	(0.40)
	99	110	96	119	96	27	547

Table 7. Least squares means and standard errors for calf crop born by cow breed

Cow Breed	LS Mean ± SE
F_2 HB	0.87 ± 0.05
F_2 BH	0.74 ± 0.06
HB x BH	0.88 ± 0.05
BH x HB	0.83 ± 0.07
NA x BH	0.79 ± 0.06
NA x HB	0.82 ± 0.11
BA x NH	0.89 ± 0.04

Table 8. Least squares means and standard errors for calf crop born by breed and age of cow

Breed	Age 2	3	4	5	6	7	8	9	10
F_2 HB	0.91 ± 0.10	0.56 ± 0.10	0.89 ± 0.11	0.91 ± 0.12	0.84 ± 0.12	0.90 ± 0.13	0.42 ± 0.26	0.96 ± 0.37	0.05 ± 0.37
F_2 BH	0.28 ± 0.10	0.73 ± 0.11	0.52 ± 0.12	0.54 ± 0.15	0.90 ± 0.19	0.91 ± 0.21	0.99 ± 0.22	1.05 ± 0.27	-
HB x BH	0.78 ± 0.09	0.52 ± 0.09	0.92 ± 0.11	0.92 ± 0.11	0.91 ± 0.11	0.85 ± 0.12	0.90 ± 0.19	0.98 ± 0.19	1.05 ± 0.23
BH x HB	0.65 ± 0.11	0.36 ± 0.11	0.77 ± 0.13	0.90 ± 0.14	0.76 ± 0.14	0.61 ± 0.16	1.03 ± 0.19	-	-
NA x BH	0.70 ± 0.08	0.68 ± 0.08	0.80 ± 0.09	0.91 ± 0.10	0.91 ± 0.12	0.71 ± 0.23	-	-	-
NA x HB	0.89 ± 0.15	0.89 ± 0.15	0.77 ± 0.16	1.00 ± 0.19	0.55 ± 0.27	-	-	-	-
BA x NH	1.02 ± 0.09	0.58 ± 0.08	0.90 ± 0.09	0.83 ± 0.09	0.85 ± 0.11	0.86 ± 0.13	0.52 ± 0.17	0.96 ± 0.26	1.05 ± 0.27
Total	0.77 ± 0.05	0.62 ± 0.04	0.80 ± 0.04	0.84 ± 0.05	0.82 ± 0.06	0.77 ± 0.09	0.75 ± 0.11	0.93 ± 0.15	0.75 ± 0.18

Table 9. Least squares means and standard errors for calf crop born by breed and birth year of cow

	Birth Year					
Breed	1996	1997	1998	1999	2000	2001
F_2 HB	0.81 ± 0.10	0.74 ± 0.11	-	0.83 ± 0.07	-	-
F_2 BH	-	0.61 ± 0.06	0.56 ± 0.11	-	-	-
HB x BH	0.83 ± 0.07	0.72 ± 0.07	-	0.88 ± 0.09	-	-
BH x HB	-	0.78 ± 0.13	0.65 ± 0.06	-	-	-
NA x BH	-	-	-	0.70 ± 0.09	0.75 ± 0.05	0.80 ± 0.11
NA x HB	-	-	-	-	0.79 ± 0.13	0.80 ± 0.11
BA x NH	0.89 ± 0.07	-	0.78 ± 0.08	0.78 ± 0.08	0.79 ± 0.13	-
Total	0.81 ± 0.05	0.71 ± 0.05	0.68 ± 0.06	0.76 ± 0.05	0.78 ± 0.07	0.82 ± 0.10

Table 10. Differences in calf crop born least squares means with standard errors between cow breeds, cow breeds born in 1997, and BA x NH cows born in different years

L[a]	LSM[c] Differences ± SE
F_2 HB – F_2 BH	0.13 ± 0.08†
F_2 HB – (HB x BH)	-0.01 ± 0.06
F_2 HB – (BH x HB)	0.04 ± 0.09
F_2 BH – (HB x BH)	-0.14 ± 0.07*
F_2 BH – (BH x HB)	-0.09 ± 0.08
(HB x BH) – (BH x HB)	0.05 ± 0.08
F_2 HB 97[b] – F_2 BH 97	0.13 ± 0.12
F_2 HB 97 – (HB x BH 97)	0.01 ± 0.12
F_2 HB 97 – (BH x HB 97)	-0.04 ± 0.17
F_2 BH 97 – (HB x BH 97)	-0.12 ± 0.09
F_2 BH 97 – (BH x HB 97)	-0.17 ± 0.14
(HB x BH 97) – (BH x HB 97)	-0.05 ± 0.15
(BA x NH 96) – (BA x NH 98)	0.11 ± 0.10
(BA x NH 96) – (BA x NH 99)	0.11 ± 0.11
(BA x NH 98) – (BA x NH 99)	0.00 ± 0.11

[a]See Table 1 for breed designations
[b]Numbers following a breed designate a year of birth
[c]Least Squares Means
† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

In a separate analysis, year of record was found to be a significant source of variation ($P < 0.0001$), while breed of cow ($P > 0.10$), birth year of cow ($P > 0.10$), and the interaction between breed and birth year of cow ($P > 0.25$) were not. Note that year of record is confounded with age of cow so any differences associated with either of these effects cannot be separated. Also, as noted, birth year of cow is confounded with sire breed of cow. Differences between adjusted means for calf crop born by breed of cow within the cow birth year of 1997, as well as BA x NH cows born in different years are presented in Table 10. Among cows born in 1997, the only year in which cows of all four breed types were born, no significant differences were found between breeds ($P > 0.10$). Between the birth years of 1996, 1998, and 1999, the years confounded between sire breed of cow and birth year of cow, BA x NH cows had no significant differences in calf crop born ($P > 0.10$).

Breed and age of cow were analyzed, and age of cow ($P < 0.05$), year of record ($P < 0.0001$), and the interaction between age and breed of cow ($P < 0.01$) were found to be significant sources of variation. Differences in adjusted means of calf crop born by breed and age of cow are presented in Table 11. As 2-year-olds, F_2 HB cows had a 0.63 ± 0.13 higher percent calf crop born than F_2 BH cows ($P < 0.001$) and a 0.26 ± 0.15 higher percent calf crop born than BH x HB cows ($P < 0.10$). HB x BH cows had a 0.50 ± 0.12 higher percent calf crop born than F_2 BH cows ($P < 0.001$), and BH x HB cows also had a 0.37 ± 0.14 higher percent calf crop born than F_2 BH cows ($P < 0.01$). However, there were no significant differences found between cow breeds as 6-year-olds ($P > 0.10$). Even though the analysis showed an interaction between breed and age of cow, there was not a statistically significant sire breed of cow effect. However, confounding prevents the ability to give a confident conclusion as to the causes of the differences noted.

Table 11. Differences in calf crop born least squares means with standard errors between cow breeds by age of cow

	Age							
L	2	3	4	5	6	7	8	9
F_2 HB - F_2 BH	0.63 ± 0.13***	-0.16 ± 0.14	0.37 ± 0.16*	0.36 ± 0.19†	-0.05 ± 0.22	-0.01 ± 0.25	-0.57 ± 0.33†	-0.09 ± 0.45
F_2 HB - (HB x BH)	0.13 ± 0.12	0.05 ± 0.13	-0.04 ± 0.15	-0.02 ± 0.15	-0.07 ± 0.16	0.05 ± 0.16	-0.48 ± 0.31	-0.02 ± 0.40
F_2 HB - (BH x HB)	0.26 ± 0.15†	0.20 ± 0.15	0.11 ± 0.17	0.01 ± 0.18	0.08 ± 0.18	0.29 ± 0.20	-0.60 ± 0.32†	-
F_2 BH - (HB x BH)	-0.50 ± 0.12***	0.21 ± 0.13	-0.40 ± 0.15**	-0.38 ± 0.18*	-0.02 ± 0.21	0.06 ± 0.24	0.09 ± 0.28	0.07 ± 0.32
F_2 BH - (BH x HB)	-0.37 ± 0.14**	0.36 ± 0.15*	-0.25 ± 0.17	-0.35 ± 0.20†	0.13 ± 0.23	0.30 ± 0.26	-0.04 ± 0.28	-
(HB x BH) - (BH x HB)	0.13 ± 0.14	0.15 ± 0.14	0.15 ± 0.17	0.03 ± 0.17	0.15 ± 0.18	0.24 ± 0.20	-0.12 ± 0.27	-

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

Calf Survival

Unadjusted means for calf survival by breed and age of cow are presented in Table 12, and unadjusted means by breed and birth year of cow are presented in Table 13. As with percent calf crop born, F_2 HB cows had the highest percent of calves survive to weaning, and F_2 BH cows had the lowest percent of calves survive to weaning.

Adjusted means for calf survival by breed of cow are presented in Table 14. Adjusted means by breed and age of cow are presented in Table 15 while adjusted means by breed and birth year of cow are presented in Table 16. The adjusted means for F_2 HB, F_2 BH, HB x BH, and BH x HB were 0.97 ± 0.05, 0.81 ± 0.07, 0.96 ± 0.04, and 0.79 ± 0.07, respectively. The fixed effects of sire breed of cow ($P < 0.05$) and the combination of year of record with age of cow ($P < 0.05$) were both significant sources of variation. Differences between adjusted means of calf survival by breed of cow are presented in Table 17. F_2 HB cows had a 0.16 ± 0.08 higher rate of calf survival than F_2 BH cows ($P < 0.10$) and a 0.18 ± 0.09 higher rate of calf survival than BH x HB cows ($P < 0.05$). HB x BH cows had a 0.14 ± 0.08 higher percent of calves survive to weaning than did F_2 BH cows ($P < 0.10$) and a 0.16 ± 0.08 higher calf survival rate than BH x HB cows ($P < 0.05$).

Table 12. Unadjusted means, standard deviations, and numbers of observations for calf survival by breed and age of cow

	Age								
Breed	2	3	4	5	6	7	8	9	Total
F_2 HB	1.0	0.89	1.0	1.0	1.0	1.0	1.0	0.0	0.96
	(0.0)	(0.33)	(0.0)	(0.0)	(0.0)	(0.0)	(-)	(-)	(0.19)
	12	9	11	11	9	3	1	1	57
F_2 BH	0.63	0.89	1.0	0.75	0.75	1.0	1.0	-	0.83
	(0.52)	(0.33)	(0.0)	(0.50)	(0.50)	(0.0)	(0.0)		(0.38)
	8	9	6	4	4	3	2		36
HB x BH	1.0	0.83	0.91	1.0	1.0	0.67	1.0	1.0	0.93
	(0.0)	(0.39)	(0.30)	(0.0)	(0.0)	(0.52)	(0.0)	(0.0)	(0.25)
	16	12	11	12	11	6	4	3	75
BH x HB	0.88	0.75	1.0	1.0	0.86	1.0	0	-	0.90
	(0.35)	(0.50)	(0.0)	(0.0)	(0.38)	(0.0)	(-)		(0.30)
	8	4	8	8	7	4	1		40
NA x BH	0.90	0.79	0.89	1.0	1.0	-	-	-	0.90
	(0.31)	(0.42)	(0.32)	(0.0)	(0.0)				(0.31)
	20	19	19	17	3				78
NA x HB	0.67	0.83	1.0	1.0	-	-	-	-	0.84
	(0.52)	(0.41)	(0.0)	(0.0)					(0.37)
	6	6	5	2					19
BA x NH	0.79	0.87	0.78	0.94	1.0	0.50	0.33	0.50	0.82
	(0.42)	(0.35)	(0.43)	(0.24)	(0.0)	(0.58)	(0.58)	(0.71)	(0.39)
	19	15	18	17	10	4	3	2	88
Total	0.87	0.84	0.91	0.97	0.95	0.80	0.73	0.67	0.89
	(0.34)	(0.37)	(0.29)	(0.17)	(0.21)	(0.41)	(0.47)	(0.52)	(0.32)
	89	74	78	71	44	20	11	6	393

Table 13. Unadjusted means, standard deviations, and numbers of observations for calf survival by breed and birth year of cow

Breed	Birth Year 1996	1997	1998	1999	2000	2001	Total
F_2 HB	0.93	1.0	-	0.97	-	-	0.96
	(0.27)	(0.0)		(0.18)			(0.19)
	14	11		32			57
F_2 BH	-	0.82	0.88	-	-	-	0.83
		(0.39)	(0.35)				(0.38)
		28	8				36
HB x BH	0.93	0.92	-	0.95	-	-	0.93
	(0.26)	(0.27)		(0.22)			(0.25)
	29	26		20			75
BH x HB	-	0.63	0.97	-	-	-	0.90
		(0.52)	(0.18)				(0.30)
		8	32				40
NA x BH	-	-	-	0.93	0.89	0.89	0.90
				(0.26)	(0.32)	(0.33)	(0.31)
				15	54	9	78
NA x HB	-	-	-	-	1.0	0.73	0.84
					(0.0)	(0.47)	(0.37)
					8	11	19
BA x NH	0.73	-	0.92	0.82	0.88	-	0.82
	(0.45)		(0.28)	(0.39)	(0.35)		(0.39)
	33		25	22	8		88
Total	0.84	0.86	0.94	0.92	0.90	0.80	0.89
	(0.37)	(0.35)	(0.24)	(0.27)	(0.30)	(0.41)	(0.32)
	76	73	65	89	70	20	393

Table 14. Least squares means and standard errors for calf survival by cow breed

Cow Breed	LS Mean ± SE
F_2 HB	0.97 ± 0.05
F_2 BH	0.81 ± 0.07
HB x BH	0.96 ± 0.04
BH x HB	0.79 ± 0.07
NA x BH	0.89 ± 0.06
NA x HB	0.88 ± 0.10
BA x NH	0.79 ± 0.04

Table 15. Least squares means and standard errors for calf survival by breed and age of cow

	Age							
Breed	2	3	4	5	6	7	8	9
F_2 HB	1.03 ± 0.09	0.84 ± 0.10	1.05 ± 0.10	0.98 ± 0.10	0.96 ± 0.11	1.07 ± 0.18	0.99 ± 0.30	-0.05 ± 0.31
F_2 BH	0.62 ± 0.12	0.78 ± 0.11	0.98 ± 0.13	0.71 ± 0.15	0.83 ± 0.15	0.98 ± 0.18	0.95 ± 0.22	-
HB x BH	1.04 ± 0.09	0.81 ± 0.09	0.92 ± 0.09	0.97 ± 0.09	1.00 ± 0.10	0.71 ± 0.13	0.98 ± 0.16	0.95 ± 0.19
BH x HB	0.79 ± 0.12	0.73 ± 0.15	0.93 ± 0.11	1.08 ± 0.11	0.87 ± 0.12	0.96 ± 0.16	-0.05 ± 0.31	-
NA x BH	0.86 ± 0.07	0.85 ± 0.08	0.90 ± 0.08	0.96 ± 0.09	0.95 ± 0.19	-	-	-
NA x HB	0.71 ± 0.13	0.86 ± 0.13	0.97 ± 0.14	0.95 ± 0.22	-	-	-	-
BA x NH	0.77 ± 0.08	0.87 ± 0.08	0.74 ± 0.07	0.96 ± 0.08	0.96 ± 0.10	0.56 ± 0.15	0.33 ± 0.18	0.45 ± 0.22
Total	0.86 ± 0.04	0.85 ± 0.04	0.90 ± 0.04	0.95 ± 0.05	0.91 ± 0.07	0.80 ± 0.09	0.67 ± 0.11	0.54 ± 0.15

Table 16. Least squares means and standard errors for calf survival by breed and birth year of cow

	Birth Year					
Breed	1996	1997	1998	1999	2000	2001
F_2 HB	0.94 ± 0.10	1.00 ± 0.10	-	0.97 ± 0.06	-	-
F_2 BH	-	0.80 ± 0.07	0.86 ± 0.12	-	-	-
HB x BH	0.91 ± 0.07	0.94 ± 0.07	-	0.95 ± 0.08	-	-
BH x HB	-	0.58 ± 0.12	0.97 ± 0.06	-	-	-
NA x BH	-	-	-	0.93 ± 0.09	0.89 ± 0.05	0.91 ± 0.11
NA x HB	-	-	-	-	1.00 ± 0.12	0.76 ± 0.10
BA x NH	0.72 ± 0.06	-	0.91 ± 0.07	0.81 ± 0.08	0.88 ± 0.12	-
Total	0.82 ± 0.05	0.85 ± 0.05	1.01 ± 0.06	0.88 ± 0.05	0.89 ± 0.07	0.81 ± 0.10

Table 17. Differences in calf survival least squares means with standard errors between cow breeds, cow breeds born in 1997, and BA x NH cows born in different years

L	LSM Differences ± SE
F_2 HB – F_2 BH	0.16 ± 0.08†
F_2 HB – (HB x BH)	0.02 ± 0.06
F_2 HB – (BH x HB)	0.18 ± 0.09*
F_2 BH – (HB x BH)	-0.14 ± 0.08†
F_2 BH – (BH x HB)	0.02 ± 0.09
(HB x BH) – (BH x HB)	0.16 ± 0.08*
F_2 HB 97 – F_2 BH 97	0.20 ± 0.12†
F_2 HB 97 – (HB x BH 97)	0.06 ± 0.12
F_2 HB 97 – (BH x HB 97)	0.43 ± 0.16**
F_2 BH 97 – (HB x BH 97)	-0.14 ± 0.09
F_2 BH 97 – (BH x HB 97)	0.22 ± 0.14
(HB x BH 97) – (BH x HB 97)	0.36 ± 0.14**
(BA x NH 96) – (BA x NH 98)	-0.19 ± 0.09†
(BA x NH 96) – (BA x NH 99)	-0.09 ± 0.10
(BA x NH 98) – (BA x NH 99)	0.10 ± 0.10

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

Separate analysis showed breed of cow ($P < 0.05$), birth year of cow ($P < 0.10$), and year of record ($P < 0.05$) all to be significant sources of variation. Differences between adjusted means of calf survival by breed of cow within the cow birth year of 1997 along with BA x NH cows born in different years are also presented in Table 17. Among those cows born in 1997, BH x HB cows had a 0.43 ± 0.16 lower percent of calves surviving to weaning than F_2 HB cows ($P < 0.01$) and a 0.36 ± 0.14 lower rate of calf survival than HB x BH cows ($P < 0.01$). F_2 BH cows had a 0.20 ± 0.12 lower rate of calf survival than F_2 HB cows ($P < 0.15$), and a 0.14 ± 0.09 lower rate of calf survival than HB x BH cows, which approached significance ($P < 0.15$). Also in that analysis, BA x NH cows born in 1998 had a 0.19 ± 0.09 higher percentage of calves surviving to weaning than did cows of the same breed born in 1996 ($P < 0.10$). This substantiates a difference between birth years of cows, but does not explain differences seen in the F_2 Brahman-Hereford crosses.

The cows with BH sires born in 1998 performed similarly to those cows with HB sires born in other years, but across all birth years, cows with BH sires could not overcome the poor performance seen in those BH-sired cows born in 1997.

In another analysis, breed of cow ($P < 0.05$), age of cow ($P < 0.01$), year of record ($P < 0.05$), and the interaction between breed and age of cow ($P < 0.05$) were all found to be significant sources of variation. Differences between adjusted means of calf survival by breed and age of cow are presented in Table 18. As 2-year-olds, F_2 HB cows had a 0.41 ± 0.14 higher rate of calf survival than F_2 BH cows ($P < 0.01$), and also had a 0.24 ± 0.15 higher rate of calf survival than BH x HB cows which approached significance ($P < 0.15$). HB x BH cows had a 0.42 ± 0.13 higher rate of calf survival than F_2 BH cows ($P < 0.01$) and a 0.25 ± 0.14 higher rate of calf survival than BH x HB cows ($P < 0.10$). As 6-year-olds, there were no significant differences found between breed combinations for calf survival.

Table 18. Differences in calf survival least squares means with standard errors between cow breeds by age of cow

	Age							
L	2	3	4	5	6	7	8	9
F_2 HB - F_2 BH	0.41 ± 0.14**	0.06 ± 0.15	0.06 ± 0.16	0.27 ± 0.18	0.13 ± 0.19	0.09 ± 0.25	0.04 ± 0.37	-
F_2 HB - (HB x BH)	-0.01 ± 0.12	0.02 ± 0.13	0.13 ± 0.13	0.01 ± 0.13	-0.04 ± 0.14	0.35 ± 0.21†	0.01 ± 0.33	-1.00 ± 0.34**
F_2 HB - (BH x HB)	0.24 ± 0.15	0.11 ± 0.19	0.12 ± 0.15	-0.09 ± 0.15	0.09 ± 0.16	0.11 ± 0.24	1.04 ± 0.43*	-
F_2 BH - (HB x BH)	-0.42 ± 0.13**	-0.03 ± 0.15	0.06 ± 0.15	-0.26 ± 0.18	-0.17 ± 0.18	0.27 ± 0.21	-0.03 ± 0.26	-
F_2 BH - (BH x HB)	-0.17 ± 0.16	0.05 ± 0.19	0.05 ± 0.17	-0.37 ± 0.19†	-0.04 ± 0.19	0.02 ± 0.23	1.00 ± 0.37**	-
(HB x BH) - (BH x HB)	0.25 ± 0.14†	0.09 ± 0.18	-0.01 ± 0.15	-0.10 ± 0.14	0.13 ± 0.15	-0.25 ± 0.20	1.03 ± 0.34**	-

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

Calf Crop Weaned

Unadjusted means for calf crop weaned by breed and age of cow are presented in Table 19. Unadjusted means by breed and birth year of cow are presented in Table 20. As with calf crop born and calf survival, F_2 BH had the lowest percent calf crop weaned, and F_2 HB had the highest percent calf crop weaned.

Adjusted means for calf crop weaned by breed of cow are presented in Table 21. Adjusted means by breed and age of cow are presented in Table 22, and adjusted means by breed and birth year of cow are presented in Table 23. The adjusted means for F_2 HB, F_2 BH, HB x BH, and BH x HB were 0.84 ± 0.06, 0.57 ± 0.07, 0.82 ± 0.06, and 0.62 ± 0.08, respectively. Both the sire breed of cow ($P < 0.01$) and the combination of year of record with age of cow ($P < 0.001$) had significant effects on the percent calf crop weaned. Differences between adjusted means of calf crop weaned by breed of cow are presented in Table 24. F_2 HB cows had a 0.27 ± 0.09 higher percent calf crop weaned than F_2 BH cows ($P < 0.01$) and a 0.22 ± 0.11 higher percent calf crop weaned than BH x HB cows ($P < 0.05$). HB x BH cows had a 0.25 ± 0.08 higher percent calf crop weaned than F_2 BH ($P < 0.01$) and a 0.20 ± 0.10 higher percent calf crop weaned than BH x HB cows ($P < 0.05$).

Table 19. Unadjusted means, standard deviations, and numbers of observations for calf crop weaned by breed and age of cow

	Age								
Breed	2	3	4	5	6	7	8	9	Total
F_2 HB	0.86	0.57	0.92	1.0	0.90	1.0	0.50	0	0.82
	(0.36)	(0.51)	(0.29)	(0.0)	(0.32)	(0.0)	(0.71)	(-)	(0.39)
	14	14	12	11	10	3	2	1	67
F_2 BH	0.25	0.57	0.54	0.50	0.75	1.0	1.0	-	0.50
	(0.44)	(0.51)	(0.52)	(0.55)	(0.50)	(0.0)	(0.0)		(0.50)
	20	14	11	6	4	3	2		60
HB x BH	0.70	0.48	0.83	1.0	1.0	0.67	1.0	1.0	0.76
	(0.47)	(0.51)	(0.39)	(0.0)	(0.0)	(0.52)	(0.0)	(0.0)	(0.43)
	23	21	12	12	11	6	4	3	92
BH x HB	0.54	0.25	0.89	1.0	0.75	0.67	0.0	-	0.63
	(0.52)	(0.45)	(0.33)	(0.0)	(0.46)	(0.52)	(-)		(0.49)
	13	12	9	8	8	6	1		57
NA x BH	0.72	0.63	0.81	0.94	1.0	-	-	-	0.77
	(0.46)	(0.49)	(0.40)	(0.24)	(0.0)				(0.42)
	25	24	21	18	3				91
NA x HB	0.67	0.83	0.83	1.0	-	-	-	-	0.80
	(0.52)	(0.41)	(0.41)	(0.0)					(0.41)
	6	6	6	2					20
BA x NH	0.68	0.59	0.74	0.84	1.0	0.40	0.25	0.50	0.70
	(0.48)	(0.50)	(0.45)	(0.37)	(0.0)	(0.55)	(0.50)	(0.71)	(0.46)
	22	22	19	19	10	5	4	2	103
Total	0.63	0.55	0.79	0.91	0.91	0.70	0.62	0.67	0.71
	(0.49)	(0.50)	(0.41)	(0.29)	(0.28)	(0.47)	(0.51)	(0.52)	(0.45)
	123	113	90	76	46	23	13	6	490

Table 20. Unadjusted means, standard deviations, and numbers of observations for calf crop weaned by breed and birth year of cow

	Birth Year						
Breed	1996	1997	1998	1999	2000	2001	Total
F_2 HB	0.76	0.73	-	0.89	-	-	0.82
	(0.44)	(0.46)		(0.32)			(0.39)
	17	15		35			67
F_2 BH	-	0.50	0.50	-	-	-	0.50
		(0.51)	(0.52)				(0.50)
		46	14				60
HB x BH	0.73	0.69	-	0.95	-	-	0.76
	(0.45)	(0.47)		(0.22)			(0.43)
	37	35		20			92
BH x HB	-	0.50	0.66	-	-	-	0.63
		(0.53)	(0.48)				(0.49)
		10	47				57
NA x BH	-	-	-	0.74	0.77	0.80	0.77
				(0.45)	(0.42)	(0.42)	(0.42)
				19	62	10	91
NA x HB	-	-	-	-	1.0	0.67	0.80
					(0.0)	(0.49)	(0.41)
					8	12	20
BA x NH	0.62	-	0.77	0.69	0.88	-	0.70
	(0.49)		(0.43)	(0.47)	(0.35)		(0.46)
	39		30	26	8		103
Total	0.69	0.59	0.67	0.82	0.81	0.73	0.71
	(0.47)	(0.49)	(0.47)	(0.39)	(0.40)	(0.46)	(0.45)
	93	106	91	100	78	22	490

Table 21. Least squares means and standard errors for calf crop weaned by cow breed

Cow Breed	LS Mean ± SE
F_2 HB	0.84 ± 0.06
F_2 BH	0.57 ± 0.07
HB x BH	0.82 ± 0.06
BH x HB	0.62 ± 0.08
NA x BH	0.68 ± 0.08
NA x HB	0.74 ± 0.14
BA x NH	0.71 ± 0.05

Table 22. Least squares means and standard errors for calf crop weaned by breed and age of cow

	Age							
Breed	2	3	4	5	6	7	8	9
F_2 HB	0.93 ± 0.12	0.45 ± 0.12	0.92 ± 0.12	0.90 ± 0.13	0.79 ± 0.15	0.95 ± 0.24	0.39 ± 0.30	-0.15 ± 0.42
F_2 BH	0.15 ± 0.11	0.59 ± 0.12	0.51 ± 0.13	0.35 ± 0.17	0.69 ± 0.21	0.86 ± 0.25	0.86 ± 0.30	-
HB x BH	0.83 ± 0.10	0.39 ± 0.10	0.83 ± 0.12	0.89 ± 0.12	0.89 ± 0.13	0.58 ± 0.18	0.85 ± 0.22	0.85 ± 0.26
BH x HB	0.52 ± 0.13	0.27 ± 0.13	0.71 ± 0.15	0.95 ± 0.16	0.64 ± 0.16	0.55 ± 0.19	-0.12 ± 0.42	-
NA x BH	0.61 ± 0.09	0.57 ± 0.10	0.72 ± 0.11	0.85 ± 0.13	0.92 ± 0.26	-	-	-
NA x HB	0.60 ± 0.17	0.76 ± 0.18	0.74 ± 0.18	0.89 ± 0.31	-	-	-	-
BA x NH	0.83 ± 0.10	0.50 ± 0.09	0.67 ± 0.10	0.79 ± 0.10	0.86 ± 0.14	0.34 ± 0.19	0.12 ± 0.22	0.39 ± 0.31
Total	0.66 ± 0.05	0.51 ± 0.04	0.72 ± 0.05	0.80 ± 0.06	0.78 ± 0.09	0.60 ± 0.12	0.45 ± 0.15	0.44 ± 0.21

Table 23. Least squares means and standard errors for calf crop weaned by breed and birth year of cow

	Birth Year					
Breed	1996	1997	1998	1999	2000	2001
F_2 HB	0.80 ± 0.12	0.72 ± 0.12	-	0.80 ± 0.08	-	-
F_2 BH	-	0.48 ± 0.07	0.46 ± 0.13	-	-	-
HB x BH	0.76 ± 0.08	0.66 ± 0.08	-	0.86 ± 0.10	-	-
BH x HB	-	0.45 ± 0.15	0.61 ± 0.07	-	-	-
NA x BH	-	-	-	0.66 ± 0.11	0.66 ± 0.06	0.69 ± 0.15
NA x HB	-	-	-	-	0.88 ± 0.16	0.56 ± 0.13
BA x NH	0.65 ± 0.08	-	0.74 ± 0.09	0.60 ± 0.09	0.76 ± 0.16	-
Total	0.66 ± 0.06	0.59 ± 0.06	0.70 ± 0.07	0.67 ± 0.06	0.71 ± 0.08	0.62 ± 0.13

Table 24. Differences in calf crop weaned least squares means with standard errors between cow breeds, cow breeds born in 1997, and BA x NH cows born in different years

L	LSM Differences ± SE
F_2 HB – F_2 BH	0.27 ± 0.09**
F_2 HB – (HB x BH)	0.02 ± 0.08
F_2 HB – (BH x HB)	0.22 ± 0.11*
F_2 BH – (HB x BH)	-0.25 ± 0.08**
F_2 BH – (BH x HB)	-0.05 ± 0.10
(HB x BH) – (BH x HB)	0.20 ± 0.10*
F_2 HB 97 – F_2 BH 97	0.24 ± 0.14†
F_2 HB 97 – (HB x BH 97)	0.05 ± 0.14
F_2 HB 97 – (BH x HB 97)	0.27 ± 0.19
F_2 BH 97 – (HB x BH 97)	-0.18 ± 0.10†
F_2 BH 97 – (BH x HB 97)	0.03 ± 0.16
(HB x BH 97) – (BH x HB 97)	0.22 ± 0.17
(BA x NH 96) – (BA x NH 98)	-0.09 ± 0.12
(BA x NH 96) – (BA x NH 99)	0.05 ± 0.12
(BA x NH 98) – (BA x NH 99)	0.14 ± 0.13

† $(P < 0.10)$
* $(P < 0.05)$
** $(P < 0.01)$
*** $(P < 0.001)$

In a separate analysis, both breed of cow ($P < 0.05$) and year of record ($P < 0.001$) had a significant effect, while birth year of cow and the interaction between breed of cow and birth year of cow were not significant sources of variation ($P > 0.10$). As with other models, due to confounding, variation due to year of record cannot be differentiated from variation due to age of cow, nor can variation due to birth year of cow be differentiated from variation due to sire breed of cow. Differences between adjusted means of calf crop weaned by breed of cow within the cow birth year of 1997 along with BA x NH cows born in different years are also presented in Table 24. Among cows born in 1997, F_2 BH cows had a 0.24 ± 0.14 lower percent calf crop weaned than F_2 HB cows ($P < 0.10$) and a 0.18 ± 0.10 lower percent calf crop weaned than HB x BH cows ($P < 0.10$). BH x HB cows had a 0.27 ± 0.19 lower percent calf crop weaned than F_2 HB cows, which approached significance ($P < 0.20$) as did the 0.22 $\pm$ 0.17 lower percent calf crop weaned of BH x HB cows compared to HB x BH cows ($P < 0.20$). Among BA x NH cows, no differences were found between those born in 1996, 1998, or 1999 ($P > 0.10$). Although the BA x NH cows were managed in a separate herd than the F_2 Brahman-Hereford cows, these cows were at the McGregor Research Center and should help account for climatic differences between birth years.

In an additional analysis, breed of cow ($P < 0.05$), age of cow ($P < 0.001$), year of record ($P < 0.001$), and the interaction between breed and age of cow ($P < 0.01$) were significant sources of variation. Differences between adjusted means of calf crop weaned by breed and age of cow are presented in Table 25. As 2-year-olds, F_2 HB cows had a 0.79 ± 0.15 higher percent calf crop weaned than F_2 BH cows ($P < 0.001$), while

HB x BH cows had a 0.68 ± 0.14 higher percent calf crop weaned than F_2 BH cows ($P < 0.001$). F_2 HB cows also had a 0.41 ± 0.17 higher percent calf crop weaned than BH x HB cows ($P < 0.05$), and HB x BH cows had a 0.30 ± 0.16 higher percent calf crop weaned than BH x HB cows ($P < 0.10$). BH x HB cows had a 0.38 ± 0.15 higher percent calf crop born than F_2 BH ($P < 0.05$). As 6-year-olds, no significant differences were found between breed types. Based on this information, there is a difference between breed types for calf crop weaned across all ages, with those cows with HB sires having increased performance over those cows with BH sires. However, recognizing that sire breed of cow cannot be completely differentiated from birth year of cow, this cannot be confidently concluded. Also, based on analysis by age of cow, “good” cows perform well throughout all ages, and those cows that were still in the herd as 6-year-olds all performed well.

Table 25. Differences in calf crop weaned least squares means with standard errors between cow breeds by age of cow

	Age							
L	2	3	4	5	6	7	8	9
F_2 HB - F_2 BH	0.79 ± 0.15***	-0.14 ± 0.16	0.41 ± 0.18*	0.55 ± 0.22*	0.11 ± 0.25	0.09 ± 0.34	-0.47 ± 0.41	-
F_2 HB - (HB x BH)	0.11 ± 0.14	0.06 ± 0.14	0.09 ± 0.17	0.00 ± 0.17	-0.10 ± 0.18	0.36 ± 0.29	-0.46 ± 0.35	-1.00 ± 0.47*
F_2 HB - (BH x HB)	0.41 ± 0.17*	0.18 ± 0.17	0.20 ± 0.19	-0.05 ± 0.20	0.15 ± 0.21	0.40 ± 0.30	0.51 ± 0.50	-
F_2 BH - (HB x BH)	-0.68 ± 0.14***	0.20 ± 0.15	-0.32 ± 0.18†	-0.54 ± 0.21**	-0.21 ± 0.24	0.28 ± 0.29	0.01 ± 0.36	-
F_2 BH - (BH x HB)	-0.38 ± 0.15*	0.32 ± 0.17†	-0.21 ± 0.19	-0.60 ± 0.22**	0.05 ± 0.26	0.32 ± 0.29	0.98 ± 0.50†	-
(HB x BH) - (BH x HB)	0.30 ± 0.16†	0.12 ± 0.16	0.11 ± 0.19	-0.06 ± 0.20	0.25 ± 0.20	0.04 ± 0.25	0.97 ± 0.46*	-

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

Birth Weight

Unadjusted means for calf birth weight by breed and age of dam are presented in Table 26, and unadjusted means by breed and birth year of dam are presented in Table 27. The F_2 BH cows had calves with the heaviest birth weight, and HB x BH cows had calves with the lightest birth weight.

Adjusted means for calf birth weight by breed of dam are presented in Table 28. Adjusted means by breed and age of dam are presented in Table 29, and adjusted means by breed and birth year of dam are presented in Table 30. The adjusted means for calf birth weight for F_2 HB, F_2 BH, HB x BH, and BH x HB dams were 38.38 ± 1.54 kg, 41.94 ± 1.72 kg, 37.73 ± 1.52 kg, and 41.03 ± 1.71 kg, respectively. Sire breed of dam ($P < 0.01$), sire breed of calf ($P < 0.05$), sex of calf ($P < 0.01$) and the combination of year of record with age of dam ($P < 0.001$) were significant sources of variation. Differences between adjusted means of calf birth weights by breed of dam are presented in Table 31.

Table 26. Unadjusted means, standard deviations, and numbers of observations for calf birth weight (kg) by breed and age of dam

	Age									
Breed	2	3	4	5	6	7	8	9	10	Total
F_2 HB	31.68	34.88	35.22	35.54	35.20	35.28	38.10	20.87	-	34.35
	(1.87)	(5.68)	(3.69)	(4.35)	(5.73)	(2.85)	(-)	(-)		(4.54)
	13	9	11	11	10	9	1	1		65
F_2 BH	35.04	34.02	38.41	37.65	39.24	37.80	36.29	37.19	-	36.50
	(2.42)	(2.42)	(6.68)	(3.01)	(12.16)	(2.92)	(3.27)	(5.13)		(5.12)
	8	8	6	4	4	3	3	2		38
HB x BH	31.33	31.59	32.06	34.32	36.45	35.98	36.97	33.79	36.59	33.69
	(3.47)	(5.26)	(6.59)	(3.69)	(2.46)	(4.28)	(2.39)	(3.00)	(1.89)	(4.60)
	16	11	12	12	11	9	4	4	3	82
BH x HB	29.94	33.34	37.54	37.65	38.88	40.14	39.01	-	-	36.35
	(6.96)	(4.82)	(3.46)	(5.94)	(7.43)	(5.36)	(3.85)			(6.40)
	8	4	8	8	7	4	4			43
NA x BH	34.22	33.76	36.24	38.24	37.44	29.03	-	-	-	35.78
	(3.86)	(5.85)	(4.98)	(5.81)	(3.23)	(10.26)				(5.28)
	20	19	19	20	15	2				95
NA x HB	33.93	35.38	35.92	42.41	38.10	-	-	-	-	36.63
	(3.37)	(10.86)	(4.24)	(5.56)	(-)					(7.01)
	5	6	5	4	1					21
BA x NH	26.88	35.50	35.13	39.54	37.32	38.22	42.03	37.65	31.75	35.04
	(5.96)	(3.44)	(5.37)	(4.82)	(8.48)	(7.64)	(6.87)	(3.21)	(3.85)	(7.18)
	19	15	18	17	11	8	3	2	2	95
Total	31.44	34.07	35.48	37.65	37.16	36.55	38.47	33.97	34.65	35.18
	(5.08)	(5.49)	(5.28)	(5.24)	(5.99)	(5.53)	(4.14)	(5.95)	(3.54)	(5.78)
	89	72	79	76	59	35	15	9	5	439

Table 27. Unadjusted means, standard deviations, and numbers of observations for calf birth weight (kg) by breed and birth year of dam

	Birth Year						
Breed	1996	1997	1998	1999	2000	2001	Total
F_2 HB	34.34	33.19	-	34.70	-	-	34.35
	(4.74)	(4.14)		(4.63)			(4.54)
	14	12		39			65
F_2 BH	-	35.63	39.31	-	-	-	36.50
		(4.96)	(4.84)				(5.12)
		29	9				38
HB x BH	34.68	34.19	-	31.87	-	-	33.69
	(3.44)	(3.69)		(6.22)			(4.60)
	31	27		24			82
BH x HB	-	37.99	35.97	-	-	-	36.35
		(5.07)	(6.68)				(6.40)
		8	35				43
NA x BH	-	-	-	34.05	36.54	34.02	35.78
				(5.24)	(5.06)	(5.99)	(5.28)
				17	66	12	95
NA x HB	-	-	-	-	36.39	36.82	36.63
					(5.06)	(8.41)	(7.01)
					9	12	21
BA x NH	34.89	-	32.44	37.60	35.48	-	35.04
	(5.94)		(7.73)	(7.59)	(7.38)		(7.18)
	35		25	26	9		95
Total	34.71	34.98	35.13	34.67	36.41	35.42	35.18
	(4.84)	(4.55)	(7.17)	(6.17)	(5.28)	(7.28)	(5.78)
	80	76	69	106	84	24	439

Table 28. Least squares means and standard errors for calf birth weight (kg) by breed of dam

Dam Breed	LS Mean ± SE
F_2 HB	38.38 ± 1.54
F_2 BH	41.94 ± 1.72
HB x BH	37.73 ± 1.52
BH x HB	41.03 ± 1.71
NA x BH	35.58 ± 1.36
NA x HB	37.08 ± 2.02
BA x NH	36.70 ± 1.15

Table 29. Least squares means and standard errors for calf birth weight (kg) by breed and age of dam

Breed	Age 2	3	4	5	6	7	8	9	10
F_2 HB	29.46 ± 1.97	34.99 ± 2.62	34.30 ± 2.84	34.28 ± 2.78	33.66 ± 2.84	35.43 ± 2.93	35.82 ± 5.56	18.58 ± 5.61	-
F_2 BH	34.44 ± 2.33	34.65 ± 3.29	37.20 ± 3.17	38.01 ± 3.38	38.73 ± 3.42	36.67 ± 3.78	35.20 ± 3.80	39.21 ± 4.40	-
HB x BH	29.24 ± 1.98	31.18 ± 2.45	31.54 ± 2.84	33.90 ± 2.71	35.34 ± 2.75	35.60 ± 2.83	34.82 ± 3.52	31.29 ± 3.57	35.67 ± 4.03
BH x HB	31.72 ± 2.22	32.36 ± 3.57	37.73 ± 2.91	36.97 ± 2.96	38.06 ± 3.07	37.79 ± 3.52	38.67 ± 3.54	-	-
NA x BH	33.73 ± 1.98	36.61 ± 1.86	37.48 ± 1.73	38.19 ± 1.77	37.13 ± 2.04	28.44 ± 3.94	-	-	-
NA x HB	33.34 ± 2.80	38.00 ± 2.47	36.49 ± 2.65	40.67 ± 2.86	38.85 ± 5.26	-	-	-	-
BA x NH	27.23 ± 1.88	38.34 ± 1.99	38.58 ± 1.82	41.42 ± 1.82	39.39 ± 1.99	38.97 ± 2.21	43.88 ± 3.21	36.63 ± 3.89	31.80 ± 3.93
Total	32.48 ± 1.08	36.17 ± 0.98	37.45 ± 0.99	38.94 ± 1.06	38.78 ± 1.26	38.71 ± 1.60	39.64 ± 2.01	35.61 ± 2.41	36.95 ± 3.05

Table 30. Least squares means and standard errors for calf birth weight (kg) by breed and birth year of dam

	Birth Year					
Breed	1996	1997	1998	1999	2000	2001
F_2 HB	34.48 ± 2.06	33.27 ± 2.10	-	33.28 ± 1.36	-	-
F_2 BH	-	36.20 ± 1.67	39.52 ± 2.20	-	-	-
HB x BH	34.66 ± 1.63	33.48 ± 1.69	-	30.41 ± 1.61	-	-
BH x HB	-	37.09 ± 2.43	35.74 ± 1.41	-	-	-
NA x BH	-	-	-	33.89 ± 1.67	36.64 ± 1.17	33.56 ± 1.92
NA x HB	-	-	-	-	36.17 ± 2.16	36.58 ± 1.93
BA x NH	37.22 ± 1.51	-	35.09 ± 1.46	37.48 ± 1.48	35.72 ± 2.20	-
Total	36.78 ± 1.17	35.33 ± 1.24	34.99 ± 1.21	34.82 ± 1.02	36.35 ± 1.31	34.56 ± 1.84

Table 31. Differences in calf birth weight (kg) least squares means with standard errors between dam breeds, dam breeds born in 1997, and BA x NH dams born in different years

L	LSM Differences ± SE
F_2 HB – F_2 BH	-3.56 ± 1.54*
F_2 HB – (HB x BH)	0.65 ± 1.14
F_2 HB – (BH x HB)	-2.65 ± 1.65
F_2 BH – (HB x BH)	4.21 ± 1.44**
F_2 BH – (BH x HB)	0.91 ± 1.59
(HB x BH) – (BH x HB)	-3.30 ± 1.58*
F_2 HB 97 – F_2 BH 97	-2.93 ± 2.05
F_2 HB 97 – (HB x BH 97)	-0.21 ± 2.08
F_2 HB 97 – (BH x HB 97)	-3.82 ± 2.72
F_2 BH 97 – (HB x BH 97)	2.72 ± 1.64†
F_2 BH 97 – (BH x HB 97)	-0.89 ± 2.38
(HB x BH 97) – (BH x HB 97)	-3.61 ± 2.42
(BA x NH 96) – (BA x NH 98)	2.13 ± 1.72
(BA x NH 96) – (BA x NH 99)	-0.26 ± 1.75
(BA x NH 98) – (BA x NH 99)	-2.39 ± 1.74

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

Calves out of F_2 BH dams were 3.56 ± 1.54 kg heavier than calves out of F_2 HB dams (P < 0.05), and 4.21 ± 1.44 kg heavier than calves out of HB x BH dams (P < 0.01). Calves out of BH x HB dams were 2.65 ± 1.65 kg heavier than calves out of F_2 HB dams, which approached significance (P < 0.15), and 3.30 ± 1.58 kg heavier than calves out of HB x BH dams (P < 0.05).

Analysis of breed and birth year of dam revealed significant sources of variation due to breed of dam (P < 0.05), sex of calf (P < 0.001), and year of record (P < 0.001). As previously noted, birth year of dam and sire breed of dam are confounded, as well as year of record and age of cow. Differences between adjusted means of calf birth weight by breed of dam within the dam birth year of 1997 along with BA x NH dams born in different years are presented in Table 31. Among cows born in 1997, only calves out of F_2 BH dams and HB x BH dams significantly differed (P < 0.10) with those calves out of F_2 BH dams being 2.72 ± 1.64 kg heavier at birth.

Also, observing calves out of BA x NH dams, no significant differences were found between calves out of dams born in 1996, 1998, or 1999, further showing the lack of effect between birth years of dams due to climatic differences. However, there could be pasture or herd differences between the BA x NH and F_2 Brahman-Hereford herds that still allow for birth year differences in the F_2 Brahman-Hereford herd.

In another analysis, breed of dam ($P < 0.05$), age of dam ($P < 0.01$), sex ($P < 0.01$), year of record ($P < 0.05$), and the interaction between breed and age of dam ($P < 0.10$) were significant sources of variation. Differences between adjusted means of calf birth weight by breed and age of cow are presented in Table 32. As 2-year-olds, calves out of F_2 BH dams were 4.98 ± 2.46 kg heavier at birth than those out of F_2 HB dams ($P < 0.05$) and 5.20 ± 2.32 kg heavier than calves out of HB x BH dams ($P < 0.05$). As 6-year-olds, calves out of F_2 HB dams were 5.07 ± 3.05 kg lighter than calves out of F_2 BH dams ($P < 0.10$), and 4.41 ± 2.63 kg lighter than calves out of BH x HB dams ($P < 0.10$). For this herd of F_2 Brahman-Herefords, calves out of dams by BH sires tended to be heavier than those out of dams by HB sires.

Table 32. Differences in calf birth weight (kg) least squares means with standard errors between dam breeds by age of dam

	Age							
L	2	3	4	5	6	7	8	9
F_2 HB - F_2 BH	-4.98 ± 2.46*	0.34 ± 2.73	-2.90 ± 2.65	-3.73 ± 3.07	-5.07 ± 3.05†	-1.24 ± 3.53	0.463 ± 5.78	-20.62 ± 6.26**
F_2 HB - (HB x BH)	0.21 ± 2.01	3.80 ± 2.28†	2.76 ± 2.12	0.37 ± 2.14	-1.69 ± 2.22	-0.17 ± 2.43	1.00 ± 5.49	-12.70 ± 5.49*
F_2 HB - (BH x HB)	-2.26 ± 2.61	2.63 ± 3.17	-3.43 ± 2.46	-2.70 ± 2.54	-4.41 ± 2.63†	-2.36 ± 3.24	-2.85 ± 5.67	-
F_2 BH - (HB x BH)	5.20 ± 2.32*	3.46 ± 2.72	5.67 ± 2.58*	4.11 ± 2.96	3.38 ± 2.95	1.07 ± 3.40	0.38 ± 3.88	7.92 ± 4.47†
F_2 BH - (BH x HB)	2.72 ± 2.72	2.29 ± 3.20	-0.53 ± 2.78	1.04 ± 3.12	0.66 ± 3.24	-1.12 ± 3.82	-3.48 ± 3.86	-
HB x BH - (BH x HB)	-2.48 ± 2.61	-1.17 ± 3.16	-6.19 ± 2.43*	-3.07 ± 2.44	-2.72 ± 2.60	-2.19 ± 3.12	-3.85 ± 3.74	-

† ($P < 0.10$)
* ($P < 0.05$)
** ($P < 0.01$)
*** ($P < 0.001$)

Weaning Weight

Unadjusted means for calf weaning weight by breed and age of dam are presented in Table 33, while unadjusted means by breed and birth year of dam are presented in Table 34. Calves out of F_2 HB dams weaned the heaviest, while calves out of F_2 BH weaned the lightest.

Adjusted means for calf weaning weight by breed of dam are presented in Table 35. Adjusted means by breed and age of dam are presented in Table 36, and adjusted means by breed and birth year of dam are presented in Table 37. The adjusted means for calf weaning weight for F_2 HB, F_2 BH, HB x BH, and BH x HB dams were 222.65 ± 5.80 kg, 221.26 ± 7.46 kg, 214.03 ± 5.39 kg, and 224.47 ± 8.26 kg, respectively. Significant sources of variation for calf weaning weight were sex of calf ($P < 0.001$), age of calf at weaning ($P < 0.001$), and the combination of year of record with age of dam ($P < 0.001$). Differences between adjusted means of calf weaning weights by breed of dam are presented in Table 38. No significant differences were found between breeds of dams for calf weaning weight.

Table 33. Unadjusted means, standard deviations, and numbers of observations for calf weaning weight (kg) by breed and age of dam

	Age								
Breed	2	3	4	5	6	7	8	9	Total
F_2 HB	204.65	208.60	234.14	230.59	233.25	222.41	256.74	-	222.91
	(22.58)	(29.15)	(27.40)	(22.98)	(14.98)	(15.66)	(-)		(25.97)
	12	8	11	11	9	3	1		55
F_2 BH	176.18	201.46	218.26	247.51	217.88	158.91	205.48	-	202.86
	(30.97)	(20.85)	(28.79)	(27.30)	(40.13)	(29.03)	(19.25)		(34.87)
	5	8	6	3	3	3	2		30
HB x BH	176.56	194.55	212.10	212.09	245.69	223.85	212.74	218.03	207.71
	(28.35)	(31.28)	(25.68)	(18.14)	(19.86)	(34.07)	(24.04)	(33.57)	(33.49)
	16	10	10	12	11	4	4	3	70
BH x HB	169.58	211.68	229.24	244.26	232.01	245.62	-	-	221.80
	(30.70)	(24.98)	(33.68)	(29.86)	(31.84)	(32.02)			(40.00)
	7	3	8	8	6	4			36
NA x BH	237.38	210.35	226.13	235.74	237.23	-	-	-	228.45
	(40.42)	(31.29)	(33.19)	(43.89)	(43.96)				(38.33)
	18	15	17	17	3				70
NA x HB	226.12	208.56	230.70	250.84	-	-	-	-	225.15
	(29.64)	(18.96)	(33.40)	(5.77)					(27.60)
	4	5	5	2					16
BA x NH	188.55	214.83	221.45	215.66	219.22	244.49	252.20	240.41	213.13
	(42.40)	(40.62)	(32.94)	(27.50)	(33.88)	(57.09)	(-)	(-)	(37.30)
	15	13	14	16	10	2	1	1	72
Total	199.41	207.29	224.48	228.09	232.18	219.43	221.36	223.62	217.22
	(41.50)	(30.53)	(30.49)	(32.02)	(28.20)	(42.49)	(31.06)	(22.60)	(35.67)
	77	62	71	69	42	16	8	4	349

Table 34. Unadjusted means, standard deviations, and numbers of observations for calf weaning weight (kg) by breed and birth year of dam

	Birth Year of Dam						
Breed	1996	1997	1998	1999	2000	2001	Total
F_2 HB	214.34	213.31	-	229.90	-	-	222.91
	(28.57)	(28.06)		(22.56)			(25.97)
	13	11		31			55
F_2 BH	-	201.16	208.46	-	-	-	202.86
		(33.13)	(42.47)				(34.87)
		23	7				30
HB x BH	210.75	200.83	-	212.07	-	-	207.71
	(28.05)	(39.50)		(32.73)			(33.49)
	27	24		19			70
BH x HB	-	254.47	216.52	-	-	-	221.80
		(50.03)	(36.41)				(40.00)
		5	31				36
NA x BH	-	-	-	211.41	233.72	226.69	228.45
				(38.58)	(38.54)	(31.15)	(38.33)
				14	48	8	70
NA x HB	-	-	-	-	223.34	226.97	225.15
					(29.43)	(27.54)	(27.60)
					8	8	16
BA x NH	219.67	-	198.28	212.33	241.57	-	213.13
	(36.82)		(38.49)	(34.86)	(20.78)		(37.30)
	24		23	18	7		72
Total	214.83	207.39	208.72	218.76	233.27	226.83	217.22
	(31.49)	(38.38)	(38.21)	(31.57)	(35.86)	(28.41)	(35.67)
	64	63	61	82	63	16	349

Table 35. Least squares means and standard errors for calf weaning weight (kg) by breed of dam

Cow Breed	LS Mean ± SE
F_2 HB	222.65 ± 5.80
F_2 BH	221.26 ± 7.46
HB x BH	214.03 ± 5.39
BH x HB	224.47 ± 8.26
NA x BH	219.59 ± 6.95
NA x HB	214.68 ± 11.62
BA x NH	220.72 ± 4.67

Table 36. Least squares means and standard errors for calf weaning weight (kg) by breed and age of dam

Breed	Age							
	2	3	4	5	6	7	8	9
F_2 HB	204.35 ± 7.96	211.45 ± 8.60	221.77 ± 7.72	219.64 ± 8.10	223.40 ± 9.51	220.59 ± 14.00	230.39 ± 22.27	-
F_2 BH	203.52 ± 11.59	218.88 ± 9.65	215.60 ± 10.00	223.13 ± 13.28	218.85 ± 13.51	184.32 ± 14.40	210.66 ± 17.32	-
HB x BH	188.48 ± 7.90	198.75 ± 8.28	216.95 ± 7.68	216.51 ± 7.32	221.10 ± 8.18	218.46 ± 12.32	225.87 ± 13.31	198.10 ± 15.57
BH x HB	190.17 ± 10.30	221.78 ± 13.45	221.05 ± 9.54	232.26 ± 9.54	231.52 ± 10.98	231.44 ± 13.26	-	-
NA x BH	234.64 ± 6.18	211.65 ± 7.03	217.59 ± 7.82	224.47 ± 9.33	225.79 ± 15.52	-	-	-
NA x HB	228.23 ± 12.27	216.06 ± 11.84	214.76 ± 12.66	212.27 ± 18.02	-	-	-	-
BA x NH	197.57 ± 7.18	220.92 ± 7.03	224.52 ± 6.65	221.56 ± 6.75	219.39 ± 8.67	232.23 ± 16.04	246.96 ± 22.24	221.26 ± 23.00
Total	205.29 ± 3.81	210.20 ± 3.49	217.79 ± 3.74	222.17 ± 5.03	226.73 ± 7.03	223.06 ± 9.55	236.74 ± 12.38	215.70 ± 15.79

Table 37. Least squares means and standard errors for calf weaning weight (kg) by breed and birth year of dam

	Birth Year					
Breed	1996	1997	1998	1999	2000	2001
F_2 HB	220.37 ± 11.35	205.98 ± 10.68	-	211.78 ± 7.12	-	-
F_2 BH	-	213.93 ± 7.12	211.43 ± 12.29	-	-	-
HB x BH	220.28 ± 8.56	200.60 ± 7.71	-	197.13 ± 9.24	-	-
BH x HB	-	253.92 ± 18.17	208.63 ± 6.94	-	-	-
NA x BH	-	-	-	200.97 ± 9.18	219.74 ± 5.28	205.52 ± 11.71
NA x HB	-	-	-	-	203.76 ± 13.28	211.66 ± 11.08
BA x NH	227.45 ± 7.95	-	211.61 ± 7.65	201.02 ± 8.81	214.24 ± 13.61	-
Total	225.30 ± 6.23	210.50 ± 6.16	204.95 ± 6.60	204.85 ± 5.17	218.85 ± 7.35	212.92 ± 11.10

Table 38. Differences in calf weaning weight (kg) least squares means with standard errors between dam breeds, dam breeds born in 1997, and BA x NH dams born in different years

L	LSM Differences ± SE
F_2 HB - F_2 BH	1.39 ± 9.33
F_2 HB – (HB x BH)	8.62 ± 7.15
F_2 HB – (BH x HB)	-1.82 ± 10.46
F_2 BH – (HB x BH)	7.23 ± 8.69
F_2 BH – (BH x HB)	-3.21 ± 10.16
(HB x BH) – (BH x HB)	-5.56 ± 9.65
F_2 HB 97 - F_2 BH 97	-7.95 ± 12.75
F_2 HB 97 – (HB x BH 97)	5.38 ± 12.90
F_2 HB 97 – (BH x HB 97)	-47.95 ± 21.01*
F_2 BH 97 – (HB x BH 97)	13.33 ± 10.36
F_2 BH 97 – (BH x HB 97)	-40.00 ± 19.48*
(HB x BH 97) – (BH x HB 97)	-53.33 ± 19.63**
(BA x NH 96) – (BA x NH 98)	15.85 ± 11.07
(BA x NH 96) – (BA x NH 99)	26.44 ± 11.93*
(BA x NH 98) – (BA x NH 99)	10.59 ± 11.56

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

A separate analysis showed that birth year of dam ($P < 0.05$) and year of record ($P < 0.001$) were significant sources of variation along with sex and weaning age of the calf as previously mentioned. Once again, noting the existence of confounding between year of record and age of dam, as well as between birth year of dam and sire breed of dam. Differences between adjusted means of calf weaning weight by breed of dam within the dam birth year of 1997 along with BA x NH dams born in different years are presented in Table 38. Among cows born in 1997, calves raised by BH x HB dams were 53.33 ± 19.63 kg heavier than calves out of HB x BH dams ($P < 0.01$), and 47.95 ± 21.01 kg heavier than calves raised by F_2 HB dams ($P < 0.05$). BH x HB dams also raised calves that were 40.00 ± 19.48 kg heavier than calves raised by F_2 BH dams ($P < 0.05$). Also in that analysis, calves raised by 1996 born BA x NH dams were 26.44 ± 11.93 kg heavier at weaning than calves raised by 1999 born BA x NH dams ($P < 0.05$). Note that BA x NH cows were maintained in a different herd.

In another analysis, the interaction between breed of dam and age of dam was a significant source of variation among calf weaning weights ($P < 0.01$) along with year of record ($P < 0.0001$), sex of calf ($P < 0.0001$), and weaning age of calf ($P < 0.0001$) as previously described. Differences between adjusted means of calf weaning weight by breed and age of cow are presented in Table 39. No significant differences ($P > 0.10$) were found between specific breeds of F_2 Brahman-Hereford dams for calf weaning weight as 2-year-olds or 6-year-olds.

Table 39. Differences in calf weaning weight (kg) least squares means with standard errors between dam breeds by age of dam

	Age						
L	2	3	4	5	6	7	8
F_2 HB – F_2 BH	0.84 ± 13.06	-7.43 ± 12.64	6.17 ± 12.55	3.49 ± 15.19	4.55 ± 15.51	36.27 ± 18.21*	19.73 ± 26.22
F_2 HB – (HB x BH)	15.87 ± 9.65	12.70 ± 11.09	4.82 ± 10.60	3.13 ± 10.26	2.30 ± 10.86	2.13 ± 16.44	4.52 ± 23.41
F_2 HB – (BH x HB)	14.18 ± 12.46	-10.33 ± 15.93	-0.72 ± 12.13	-12.62 ± 11.82	-8.12 ± 13.01	-10.85 ± 17.12	-
F_2 BH – (HB x BH)	15.03 ± 12.47	20.13 ± 12.28†	-1.35 ± 12.93	6.62 ± 14.88	-2.725 ± 14.85	-34.14 ± 17.20*	-15.21 ± 19.07
F_2 BH – (BH x HB)	13.34 ± 14.23	-2.90 ± 16.43	-5.45 ± 13.49	-9.13 ± 15.99	-12.68 ± 16.22	-47.12 ± 17.37**	-
(HB x BH) – (BH x HB)	-1.69 ± 12.13	-23.03 ± 15.68	-4.10 ± 12.21	-15.75 ± 11.66	-10.42 ± 12.46	-12.98 ± 16.18	-

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

Cow Weight at Palpation

Unadjusted means for cow weight at palpation are presented by breed and age of cow in Table 40, and unadjusted means by breed and birth year of cow are presented in Table 41. Across their lifetime, BH x HB cows were the heaviest, while HB x BH were the lightest.

Adjusted means for cow weight at palpation are presented by breed of cow in Table 42. Adjusted means by breed and age of cow are presented in Table 43, and adjusted means by breed and birth year of cow are presented in Table 44. The adjusted means for cow weight at palpation for F_2 HB, F_2 BH, HB x BH, and BH x HB cows were 493.14 ± 12.45 kg, 533.59 ± 12.76 kg, 477.00 ± 10.43 kg, and 518.11 ± 15.70 kg, respectively. Sire breed of cow ($P < 0.05$) and the combination of year of record with age of cow ($P < 0.001$) were significant sources of variation. Differences between adjusted means of cow weight at palpation by breed of cow are presented in Table 45. Averaged across all ages, HB x BH cows weighed 56.59 ± 15.29 kg less than F_2 BH cows ($P < 0.001$) and 41.11 ± 18.92 kg less than BH x HB cows ($P < 0.05$). Also, F_2 HB cows weighed 40.45 ± 17.68 kg less than F_2 BH cows ($P < 0.05$).

Table 40. Unadjusted means, standard deviations, and numbers of observations for cow weight (kg) at palpation by breed and age of cow

	Age									
Breed	1	2	3	4	5	6	7	8	9	Total
F_2 HB	379.27	403.73	512.00	511.70	531.33	577.66	519.37	526.17	591.94	479.63
	(43.84)	(49.48)	(71.41)	(68.28)	(69.74)	(63.45)	(24.00)	(-)	(-)	(91.74)
	15	14	12	11	11	10	3	1	1	78
F_2 BH	393.01	486.56	478.05	522.32	610.09	616.32	588.17	561.33	-	480.92
	(32.64)	(85.99)	(57.27)	(57.36)	(99.81)	(105.23)	(68.43)	(11.23)		(94.55)
	23	18	12	10	4	4	3	2		76
HB x BH	340.10	412.77	472.86	490.76	511.05	543.90	552.63	546.02	536.00	454.00
	(44.68)	(58.39)	(53.85)	(60.76)	(65.04)	(39.97)	(66.18)	(68.95)	(31.78)	(91.63)
	24	22	15	13	12	11	6	4	3	110
BH x HB	399.45	406.35	475.27	528.44	545.74	567.00	590.81	716.68	-	482.32
	(46.35)	(81.61)	(76.40)	(67.25)	(85.06)	(86.92)	(89.24)	(-)		(103.52)
	13	12	9	8	8	6	4	1		61
NA x BH	388.37	475.41	504.40	544.86	572.07	599.50	-	-	-	515.81
	(31.10)	(46.91)	(49.35)	(50.17)	(37.00)	(47.91)				(66.20)
	5	23	22	21	17	3				91
NA x HB	-	479.30	522.62	557.92	560.19	-	-	-	-	522.19
		(66.62)	(65.39)	(78.57)	(105.84)					(74.45)
		6	6	5	2					19
BA x NH	355.55	382.52	487.20	500.82	500.62	546.99	565.18	563.59	601.02	464.96
	(30.71)	(45.48)	(55.22)	(41.94)	(71.18)	(51.11)	(55.91)	(65.75	(70.56)	(87.94)
	13	20	13	18	12	9	5	2	2	94
Total	372.55	433.29	492.33	519.83	539.95	566.24	563.22	567.68	567.00	479.94
	(45.11)	(72.46)	(59.64)	(59.05)	(71.49)	(64.03)	(63.32)	(70.42)	(50.63)	(90.63)
	93	115	89	86	66	43	21	10	6	529

Table 41. Unadjusted means, standard deviations, and numbers of observations for cow weight (kg) at palpation by breed and birth year of cow

	Birth Year						
Breed	1996	1997	1998	1999	2000	2001	Total
F_2 HB	451.31	437.47	-	507.84	-	-	479.63
	(79.82)	(70.22)		(95.31)			(91.74)
	19	16		43			78
F_2 BH	-	481.85	478.14	-	-	-	480.92
		(93.17)	(101.15)				(94.55)
		57	19				76
HB x BH	427.62	459.75	-	489.78	-	-	454.00
	(86.11)	(96.27)		(82.36)			(91.63)
	44	40		26			110
BH x HB	-	561.76	464.85	-	-	-	482.32
		(125.87)	(90.33)				(103.52)
		11	50				61
NA x BH	-	-	-	502.40	527.39	471.39	515.81
				(84.88)	(56.86)	(53.14)	(66.20)
				22	60	9	91
NA x HB	-	-	-	-	505.08	534.63	522.19
					(84.41)	(67.72)	(74.45)
					8	11	19
BA x NH	467.02	-	458.04	453.82	513.13	-	464.96
	(92.05)		(86.66)	(92.07)	(39.30)		(87.94)
	37		20	29	8		94
Total	446.70	476.08	466.16	489.87	523.54	506.17	479.94
	(88.21)	(98.65)	(91.13)	(91.43)	(58.41)	(68.15)	(90.63)
	100	124	89	120	76	20	529

Table 42. Least squares means and standard errors for cow weight (kg) by breed of cow

Cow Breed	LS Mean ± SE
F_2 HB	493.14 ± 12.45
F_2 BH	533.59 ± 12.76
HB x BH	477.00 ± 10.43
BH x HB	518.11 ± 15.70
NA x BH	503.13 ± 15.81
NA x HB	523.77 ± 26.74
BA x NH	484.98 ± 10.11

Table 43. Least squares means and standard errors for cow weight (kg) at palpation by breed and age of cow

	Age								
Breed	1	2	3	4	5	6	7	8	9
F_2 HB	417.30 ± 16.88	425.53 ± 15.47	492.30 ± 15.37	499.51 ± 16.10	501.28 ± 17.62	523.65 ± 20.49	512.36 ± 29.06	519.95 ± 44.11	567.37 ± 46.29
F_2 BH	409.81 ± 16.33	497.61 ± 15.49	519.61 ± 15.06	553.70 ± 15.85	592.70 ± 22.29	602.61 ± 23.63	582.04 ± 27.87	564.94 ± 34.25	-
HB x BH	384.70 ± 16.87	427.33 ± 14.46	465.70 ± 14.03	486.33 ± 13.79	486.02 ± 14.80	492.84 ± 16.98	517.97 ± 22.07	513.67 ± 27.10	504.62 ± 32.16
BH x HB	409.29 ± 18.33	432.12 ± 16.89	505.74 ± 17.66	498.08 ± 18.39	513.04 ± 19.60	515.93 ± 22.96	512.92 ± 27.69	554.84 ± 44.57	-
NA x BH	405.89 ± 20.47	449.50 ± 12.50	470.33 ± 14.47	503.74 ± 17.38	513.04 ± 21.35	517.20 ± 32.13	-	-	-
NA x HB	-	445.09 ± 23.37	485.66 ± 24.97	517.88 ± 28.18	528.59 ± 37.95	-	-	-	-
BA x NH	405.37 ± 17.27	404.07 ± 13.18	469.94 ± 14.03	484.30 ± 12.91	477.61 ± 15.91	504.57 ± 19.54	525.93 ± 24.80	530.32 ± 34.52	549.38 ± 37.30
Total	401.55 ± 9.21	440.36 ± 6.41	483.90 ± 6.20	507.83 ± 8.25	514.49 ±11.85	528.72 ± 16.12	539.47 ± 20.53	544.51 ± 25.93	557.25 ± 31.40

Table 44. Least squares means and standard errors for cow weight (kg) by breed and birth year of cow

	Birth Year					
Breed	1996	1997	1998	1999	2000	2001
F_2 HB	488.81 ± 24.67	465.61 ± 22.52	-	454.03 ± 15.46	-	-
F_2 BH	-	524.27 ± 11.84	469.84 ± 17.84	-	-	-
HB x BH	476.52 ± 15.04	468.37 ± 14.48	-	433.96 ± 19.78	-	-
BH x HB	-	540.10 ± 27.35	444.63 ± 13.85	-	-	-
NA x BH	-	-	-	453.66 ± 20.09	431.55 ±11.39	365.99 ± 26.21
NA x HB	-	-	-	-	407.93 ± 31.02	434.73 ± 23.06
BA x NH	501.34 ± 16.52	-	430.02 ± 17.73	409.24 ± 18.09	415.98 ± 31.02	-
Total	509.81 ± 12.87	495.76 ±11.89	438.35 ± 13.30	453.51 ± 10.87	429.38 ± 16.17	395.87 ± 24.58

Table 45. Differences in cow weight (kg) least squares means with standard errors between cow breeds, cow breeds born in 1997, and BA x NH cows born in different years

L	LSM Differences ± SE
F_2 HB – F_2 BH	-40.45 ± 17.68*
F_2 HB – (HB x BH)	16.14 ± 15.04
F_2 HB – (BH x HB)	-24.97 ± 20.65
F_2 BH – (HB x BH)	56.59 ± 15.29***
F_2 BH – (BH x HB)	15.48 ± 17.07
(HB x BH) – (BH x HB)	-41.11 ± 18.92*
F_2 HB 97 – F_2 BH 97	-58.66 ± 25.21*
F_2 HB 97 – (HB x BH 97)	-2.75 ± 26.55
F_2 HB 97 – (BH x HB 97)	-74.48 ± 35.26*
F_2 BH 97 – (HB x BH 97)	55.90 ± 18.38**
F_2 BH 97 – (BH x HB 97)	-15.83 ± 29.59
(HB x BH 97) – (BH x HB 97)	-71.73 ± 30.74*
(BA x NH 96) – (BA x NH 98)	71.32 ± 24.29**
(BA x NH 96) – (BA x NH 99)	92.10 ± 24.59***
(BA x NH 98) – (BA x NH 99)	20.78 ± 25.16

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

Another analysis showed that breed of cow ($P < 0.05$), birth year of cow ($P < 0.001$), and year of record ($P < 0.001$) were significant sources of variation. Again, note the confounding between year of record and age of cow, as well as confounding between birth year of cow and sire breed of cow. Differences between adjusted means of cow weight at palpation by breed of cow within the cow birth year of 1997 along with BA x NH cows born in different years are presented in Table 45. Among cows born in 1997, F_2 BH cows were 58.66 ± 25.21 kg heavier than F_2 HB cows ($P < 0.05$) and 55.90 ± 18.38 kg heavier than HB x BH cows ($P < 0.01$). Also, BH x HB cows were 74.48 ± 35.26 kg heavier than F_2 HB cows ($P < 0.05$) and 71.73 ± 30.74 kg heavier than HB x BH cows ($P < 0.05$). This analysis also showed that BA x NH cows born in 1996 were 71.32 ± 24.29 kg heavier than BA x NH cows born in 1998 ($P < 0.01$) and 92.10 ± 24.59 kg heavier than BA x NH cows born in 1999 ($P < 0.001$). Note that 1996 born cows are expected to be heavier, when cow weight is averaged across their lifetime, since they are two years older than 1998 born cows and three years older than 1999 born cows. Climatic differences and age differences due to cow birth year do not explain the differences seen between the specific F_2 Brahman-Hereford breed combinations, since HB-sired cows were born in 1996 and tended to be smaller than BH-sired cows; however, cow birth year effects due to pasture and management conditions specific to the F_2 Brahman-Hereford herd could be present.

A separate analysis found breed of cow ($P < 0.001$), age of cow ($P < 0.001$), year of record ($P < 0.001$), and the interaction between breed and age of cow ($P < 0.05$) to be significant sources of variation. Differences between adjusted means of cow weight at palpation by breed and age of cow are presented in Table 46. As yearlings, HB x BH cows were 32.61 ± 18.15 kg lighter than F_2 HB cows ($P < 0.10$). As 2-year-olds, F_2 BH cows were 65.49 ± 20.69 kg heavier than BH x HB cows ($P < 0.01$), 72.08 ± 19.63 kg heavier than F_2 HB cows ($P < 0.001$), and 70.28 ± 17.14 kg heavier than HB x BH cows ($P < 0.001$). As 6-year-olds, F_2 BH cows were 86.68 ± 28.95 kg heavier than BH x HB cows ($P < 0.01$), 78.96 ± 27.38 kg heavier than F_2 HB cows ($P < 0.01$), and 109.76 ± 25.80 kg heavier than HB x BH cows ($P < 0.001$).

Table 46. Differences in cow weight (kg) least squares means with standard errors between cow breeds by age of cow

	Age								
L	1	2	3	4	5	6	7	8	9
F_2 HB – F_2 BH	7.49 ± 18.74	-72.08 ± 19.63***	-27.31 ± 21.22	-54.19 ± 22.25*	-91.41 ± 26.78***	-78.96 ± 27.38**	-69.68 ± 34.23*	-44.99 ± 49.09	-
F_2 HB – (HB x BH)	32.61 ± 18.15†	-1.80 ± 18.60	26.60 ± 20.07	13.18 ± 20.75	15.27 ± 20.97	30.80 ± 21.44	-5.61 ± 29.97	6.28 ± 44.19	62.75 ± 45.42
F_2 HB – (BH x HB)	8.01 ± 21.38	-6.59 ± 21.65	-13.43 ± 23.39	1.43 ± 23.85	-11.75 ± 23.93	-7.72 ± 25.74	-0.56 ± 33.30	34.89 ± 56.07	-
F_2 BH – (HB x BH)	25.11 ± 16.63	70.28 ± 17.14***	53.90 ± 19.53**	67.37 ± 20.62**	106.69 ± 25.54***	109.76 ± 25.80***	64.07 ± 29.85*	51.27 ± 35.76	-
F_2 BH – (BH x HB)	0.52 ± 19.02	65.49 ± 20.69**	13.87 ± 22.61	55.62 ± 23.66*	79.67 ± 27.89**	86.68 ± 28.95**	69.12 ± 32.68*	10.10 ± 48.35	-
(HB x BH) – (BH x HB)	-24.59 ± 19.98	-4.79 ± 20.06	-40.03 ± 22.42†	-11.75 ± 22.88	-27.02 ± 23.05	-23.08 ± 24.63	5.05 ± 29.04	-41.17 ± 44.99	-

† (P < 0.10)
* (P < 0.05)
** (P < 0.01)
*** (P < 0.001)

SUMMARY AND CONCLUSIONS

Calf Crop Born

Percent calf crop weaned is the most important measurement of reproductive efficiency. Calf crop weaned is a product of calf crop born and calf survival. Observation of unadjusted means gives the appearance of a sire breed of cow effect on percent calf crop born. However, the analysis of variance showed the lack of a sire breed effect ($P > 0.10$). In that analysis, individual mean difference estimates indicated that F_2 BH cows had a lower percent calf crop born than HB x BH cows ($P < 0.05$). Also, F_2 BH cows had a lower percent calf crop born than F_2 HB cows ($P < 0.10$).

Analysis by birth year of cow revealed that birth year was not a significant source of variation ($P > 0.10$). Specifically, no differences ($P > 0.10$) were noted between BA x NH cows born in different years. Also, there were no differences ($P > 0.10$) between breeds born in 1997 for percent calf crop born. Analysis by age of cow revealed that, as 2-year-olds, F_2 HB cows had a higher percent calf crop born than F_2 BH ($P < 0.001$) cows and BH x HB cows ($P < 0.10$). F_2 BH cows also had a lower percent calf crop born than HB x BH cows ($P < 0.001$) and BH x HB cows ($P < 0.01$). While the analysis of variance showed no significant sire breed of cow effect, individual differences between adjusted means show that percent calf crop born had an impact on the breed differences found in percent calf crop weaned. However, due to confounding already discussed, it is possible that adjusted means could be misrepresented. Unadjusted means show that HB-sired cows had at least a 10 percentage point higher calf crop born than BH-sired cows. Any sources of variation that were found are extremely difficult to separate due to the confounding between birth year of cow and sire breed of cow, as well as age of cow and year of record.

Calf Survival

Observation of unadjusted means suggested that only F_2 BH cows had a lower calf survival rate than the other breed types. Analysis, however, showed a significant sire breed of cow effect ($P < 0.05$) on calf survival rate. F_2 HB and HB x BH cows had a higher percent of calves survive to weaning than did F_2 BH cows ($P < 0.10$) and BH x HB cows ($P < 0.05$). Further analysis revealed that birth year of cow was a significant source of variation ($P < 0.10$). Even though analysis showed a birth year of cow effect, cows born in 1997 tended to follow the same trend as breed differences found across all birth years. BH x HB cows had a lower percent of calves surviving to weaning than F_2 HB cows ($P < 0.01$) and HB x BH cows ($P < 0.01$). F_2 BH cows had a lower rate of calf survival than F_2 HB cows ($P < 0.10$) and HB x BH cows by a difference that approached significance ($P < 0.15$). Also in that analysis, BA x NH cows born in 1998 had a higher percentage of calves surviving to weaning than did cows of the same breed born in 1996 ($P < 0.10$). This substantiates a difference between birth years of cows, but does not explain differences seen in the F_2 Brahman-Hereford crosses. Even though BH-sired cows born in 1998 had a similar calf survival rate to that of the HB-sired cows born in 1996, the BH-sired cows had a lower calf survival rate than HB-sired cows across all birth years due to the low calf survival rate of those BH-sired cows born in 1997. The trend of cows with HB sires having a higher calf survival rate than those with BH sires also held true between breed types as 2-year-olds. The differences observed between breed types for calf survival rate along with the tendencies observed between breed types for calf crop born explain the differences seen between breed types for calf crop weaned, even though the specific reason for these differences is difficult to pinpoint.

Calf Crop Weaned

As mentioned in the discussion of data for calf survival, sire breed of dam was found to be a significant source of variation ($P < 0.01$) for calf crop weaned. F_2 HB cows had a higher percent calf crop weaned than both F_2 BH ($P < 0.01$) and BH x HB cows ($P < 0.05$). HB x BH cows also had a higher percent calf crop weaned than both F_2 BH ($P < 0.01$) and BH x HB cows ($P < 0.05$). Further analysis showed that birth year of cow was not a significant source of variation ($P > 0.10$). Among cows born in 1997, F_2 BH cows had a lower percent calf crop weaned than both F_2 HB ($P < 0.10$) and HB x BH cows ($P < 0.10$). The difference between BH x HB cows and F_2 HB cows approached significance ($P < 0.20$), as did the difference between BH x HB cows and HB x BH cows ($P < 0.20$), with those cows sired by HB sires having a higher percent calf crop weaned than the BH x HB cows. This tends to follow the same observations seen across all birth years. Further evidence that climatic differences between birth years of cows may not have been the root of differences between cow breed types is that no differences ($P > 0.10$) were found between BA x NH cows born in different years. Management and pasture effects could still account for some differences found between breed types in the F_2 Brahman-Hereford herd.

While it has already been stated that birth year of cow and sire breed of cow are almost completely confounded, there is no question that, in this herd, cows with F_1 HB sires were higher in reproductive efficiency than cows by F_1 BH sires. Poor performance of the BH-sired cows is consistent with findings reported in Australia (Rendel, 1980; Mackinnon et al., 1989).

Concerning the confounding between breed type and birth year of cow, birth year of a cow represents the nutrition allowed to her and her dam in the preweaning stage of life. Differences among birth years could have an effect on a heifer's weight and condition at the time of breeding. A heifer that is small at the time of breeding may not get bred and calve as a two-year-old which delays her productivity for another year. However, BA x NH cows, while not in the same herd, were raised at the same location as the F_2 Brahman-Hereford cows, and it has been illustrated that there was no difference in the percent calf crop weaned between the BA x NH cows born in 1996, 1998, and 1999, which are the years that are confounded between birth year of cow and sire breed of cow in the F_2 Brahman-Hereford herd.

Regarding calf crop weaned percentages within cow ages, most of the cows that did calve as a 2-year-old did not calve as a 3-year-old and vice versa. Because of this, the differences between HB-sired cows and BH-sired cows are essentially reversed between the ages of two and three with the HB-sired cows performing relatively well as 2-year-olds but not as 3-year-olds and the BH-sired cows performing poorly as 2-year-olds but relatively well as 3-year-olds. As mentioned previously, "good" cows performed well throughout all ages regardless of breed type. However, there were more "good" cows by HB sires than BH sires. These cows were produced in multiple sire pastures with six HB sires and six BH sires. While the pastures were set up to be certain of breed type, the specific sire of these cows is not known. It is possible that individual sires could have had a significant impact on the reproductive efficiency of the F_2 herd. While this is unlikely with the use of six different sires, there is still the possibility that the F_2 heifers retained in the breeding herd were from particular sires and not uniform across all sires.

Appendix Table A illustrates individual weights through 30 months of age along with reproductive record of each cow. This was done in an effort to locate trends that might suggest that "poor" performing cows were too small as heifers. Appendix Table B presents weights, condition scores, and reproductive performance through four-years-of-age. These data were used to evaluate weight and nutritional status of females as they started having calves. Also, BH-sired cows, especially F_2 BH cows, tended to have younger dams than the HB-sired cows. These young dams could have produced less milk and caused many of these cows to get a "slow start" as heifers. With this data it was observed that many of the cows that were culled at an early age were smaller than their counterparts that weaned several calves. However, this trend does not explain the differences seen between breed types since, as has been discussed, the BH-sired cows tended to be heavier on average than HB-sired cows. It is well known that maintenance requirements increase as cow weight increases (Klosterman et al., 1968; Turner et al., 1974; Marshall et al., 1976; NRC, 1996). If the nutritional requirements for BH-sired cows were high enough, it is possible that they were not receiving adequate nutrition to maintain reproductive function. However, average condition scores (Appendix Table C) reveal that BH-sired cows appeared to be in just as high a condition as those cows by HB sires. While it does not explain differences between breed types, most cows that were scored below a 5 (on a 1-9 scale) did not wean a calf in the following year, regardless of breed type. Between cow birth years, 1996 born cows were smaller at 18-months-of-age (analyzed yearling weight) with a lower condition scores than cows born in other years, but these cows performed very well. A possible explanation of the heavier weights of BH-sired cows is their noted “poor” performance. BH-sired cows were dry more often at an early age allowing them to gain more weight than HB-sired cows that were producing milk. Also, since cows with “poor” performance tended to be smaller, weights within mature ages could be elevated due to the culling of smaller cows. Even with the data available, no definitive trends were found.

As mentioned several times before, confounding prevents the effects of birth year of cow from being separated from sire breed of cow. Also, effects of year of record cannot be separated from age of cow effects. Every effort has been made to differentiate the causes of differences in reproductive efficiency. In this herd, the differences and tendencies lean towards the conclusion that there is a genetic influence on reproductive efficiency based on the sire breed of cows. With that being said, more research is needed to validate these differences, as well as more accurately determine the cause of differences between reciprocally crossed F_2 Brahman x *Bos taurus* crosses.

Birth and Weaning Weight

Analysis of birth weight showed that sire breed of dam was a significant source of variation ($P < 0.01$). Significant differences were found between calves out of F_2 BH dams and F_2 HB dams ($P < 0.05$), as well as between calves out of F_2 BH dams and HB x BH dams ($P < 0.01$). Differences were also found between calves out of BH x HB dams and calves out of both F_2 HB dams, which approached significance ($P < 0.15$), and HB x BH dams ($P < 0.05$). In all of these cases, the dams sired by BH sires had calves with heavier birth weights than those out of HB-sired dams. Further analysis showed that birth year of dam was not a significant source of variation ($P > 0.10$). The only difference seen among the cows born in 1997 was a difference between calves out of F_2 BH dams and calves out of HB x BH dams with calves out of F_2 BH dams being heavier ($P < 0.10$). Analysis within age groups revealed that as 2-year-olds, calves out of F_2 BH dams were heavier at birth than calves out of F_2 HB dams ($P < 0.05$) and calves out of HB x BH dams ($P < 0.05$). As 6-year-olds, calves out of F_2 HB dams were lighter at birth than calves out of F_2 BH dams ($P < 0.10$) and BH x HB dams ($P < 0.10$).

Analysis of weaning weight did not show any significant effect of sire breed of dam ($P > 0.10$). There were also no differences found between dam breed types for calf weaning weight ($P > 0.10$). In further analysis, birth year of dam was a significant source of variation ($P < 0.05$). Among cows born in 1997, calves raised by BH x HB dams were heavier than those raised by HB x BH dams ($P < 0.01$), F_2 HB dams ($P < 0.05$), and F_2 BH dams ($P < 0.05$). Also in that analysis, calves raised by 1996 born BA x NH dams were heavier at weaning than calves raised by 1999 born BA x NH dams (P

< 0.05). As 2-year-olds, calves raised by F_2HB cows were heavier at weaning than calves raised by HB x BH cows ($P < 0.10$). However, no significant differences ($P > 0.10$) were found between specific breeds of F_2 Brahman-Hereford dams for calf weaning weight as 6-year-olds. Based on this information, any differences between dam breed types for calf birth weight are eliminated by weaning, with the exception of cows born in 1997. Among those cows born in 1997, BH-sired cows tended to raise heavier calves than HB-sired cows.

Cow Weight at Palpation

Analysis of cow weight revealed that sire breed of cow was a significant source of variation ($P < 0.05$). Averaged across all ages, HB x BH cows weighed less than F_2 BH cows ($P < 0.001$) and BH x HB cows ($P < 0.05$). F_2 HB cows also weighed less than F_2 BH cows ($P < 0.05$). Further analysis revealed that birth year was a significant source of variation ($P < 0.001$). Among cows born in 1997, F_2 BH cows were heavier than F_2 HB cows ($P < 0.05$) and HB x BH ($P < 0.01$). Also, BH x HB cows were heavier than F_2 HB cows ($P < 0.05$) and HB x BH cows ($P < 0.05$). Analysis also revealed that BA x NH cows born in 1996 were heavier than those born in 1998 ($P < 0.01$) and 1999 ($P < 0.001$). As noted earlier, some of this difference between birth years is due to the fact that 1996 born cows are older than 1998 and 1999 born cows. However, this information does not explain the differences seen between specific breed combinations of F_2 Brahman-Hereford cows because only F_2 HB and HB x BH cows were born in 1996, and those cows tended to be smaller than cows with F_1 BH sires. In this herd, cows with F_1 BH sires tended to be heavier than cows by F_1 HB sires. As explained previously, this could explain differences in performance if the increased weight contributed to these cows not being able to meet their nutrient requirements with available resources; conversely, as discussed previously, weights may have been heavier in the BH-sired groups due to their lower reproductive performance. Data from this study are summarized in Table 47. In this herd, HB-sired cows had higher reproductive efficiency than BH-sired cows. Also, HB-sired cows tended to be lighter and have lighter calves at birth than BH-sired cows, across all ages.

Table 47. Summary of least squares means for all traits analyzed by breed of cow

Cow Breed	Calf Crop Born	Calf Survival	Calf Crop Weaned	Calf Birth Weight	Calf Weaning Weight	Cow Weight
F_2 HB	0.87	0.97	0.84	38.4	222.7	493.1
F_2 BH	0.74	0.81	0.57	41.9	221.3	533.6
HB x BH	0.88	0.96	0.82	37.7	214.0	477.0
BH x HB	0.83	0.79	0.62	41.0	224.5	518.1

Conclusions

The use of F_2 females in developing composite breeds that are more easily managed by smaller producers is very important. The results of this study present additional questions in regards to the differences seen between breed types for reproductive efficiency. In this herd, cows by F_1 HB sires tended to have higher reproductive efficiency than those cows by F_1 BH sires. More research is needed in this area to answer questions raised in this study by confounding of data. If the differences between specific breed types truly are the result of a genetic difference, further research is also needed to determine the mechanism controlling these differences.

LITERATURE CITED

Bailey, C. M., Y. O. Koh, W. D. Foote and D. R. Hanks. 1990. Life-cycle evaluation of *Bos taurus* and *Bos indicus* x *Bos taurus* breed types in a dry, temperate climate: Performance of mature dams. J. Anim. Sci. 68:960-968.

Baker, A. L., and W. H. Black. 1950. Crossbred types of beef cattle for the Gulf Coast Region. USDA Circ. 844. U. S. Gov. Printing Office, Washington, D.C.

Cartwright, T. C., G. F. Ellis, Jr., W. E. Kruse, and E. K. Crouch. 1964. Hybrid vigor in Brahman-Hereford crosses. Tech. Monograph 1. Texas Agric. Exp. Sta., College Station.

Cartwright, T. C. 1980. Prognosis of Zebu cattle: Research and application. J. Anim. Sci. 50:1221-1226.

Comerford, J. W., J. K. Bertrand, L. L. Benyshek, and M. H. Johnson. 1987. Reproductive rates, birth weight, calving ease and 24-h calf survival in a four-breed diallel among Simmental, Limousin, Polled Hereford, and Brahman beef cattle. J. Anim. Sci. 64:65-76.

Crockett, J.R., M. Koger and D.E. Franke. 1978. Rotational crossbreeding of beef cattle: Reproduction by generation. J. Anim. Sci. 46:1163-1169.

Cundiff, L. V., K. E. Gregory, and R. M. Koch. 1974a. Effects of heterosis on reproduction in Hereford, Angus and Shorthorn cattle. J. Anim. Sci. 38:711-727.

Cundiff, L. V., K. E. Gregory, F. J. Schwulst, and R. M. Koch. 1974b. Effects of heterosis on maternal performance and milk production in Hereford, Angus and Shorthorn cattle. J. Anim. Sci. 38:728-745.

Cundiff, L. V. 1977. Foundations for animal breeding research. J. Anim. Sci. 44:311-319.

Cundiff, L. V., R. Nunez-Dominguez, G. E. Dickerson, K. E. Gregory, and R. M. Koch. 1992. Heterosis for lifetime production in Hereford, Angus, Shorthorn, and crossbred cows. J. Anim. Sci. 70:2397-2410.

Cundiff, L. V. 2006. The impact of quantitative genetics on productive, reproductive, and adaptive traits in beef cattle. Proceedings of Australian Beef – The Leader Conference, Univ. of New England, Armidale, N.S.W., March, 2006. pp 29-46.

Damon, R. A., Jr., S. E. McCraine, R. M. Crown and C. B. Singletary. 1959. Performance of crossbred beef cattle in the Gulf Coast region. J. Anim. Sci. 18:437-447.

Damon, R. A., Jr., W. R. Harvey, C. B. Singletary, S. E. McCraine and R. M. Crown. 1961. Genetic analysis of crossbreeding beef cattle. J. Anim. Sci. 20:849-857.

Dearborn, D. D., K. E. Gregory, L. V. Cundiff, and R. M. Koch. 1987. Maternal heterosis and grandmaternal effects in beef cattle: Preweaning traits. J. Anim. Sci. 65:33-41.

Dickerson, G. 1969. Experimental approaches in utilising breed resources. Anim. Breed. Abstr. 37:191-202.

Franke, D.E. 1980. Breed and heterosis effects of American Zebu cattle. J. Anim. Sci. 50:1206-1214.

Frisch, J. E., and J. E. Vercoe. 1978. Utilizing breed differences in growth of cattle in the tropics. World Anim. Rev. 25:8-12.

Gaines, J. A., C. Hill, W. H. McClure, R. C. Carter, and W. T. Butts. 1978. Heterosis from crosses among British breeds of cattle: Straightbred versus crossbred cows. I. J. Anim. Sci. 47:1246-1253.

Gregory, K. E., L. A. Swiger, R. M. Koch, L. J. Sumption, W. W. Rowden and J. E. Ingalls. 1965. Heterosis in preweaning traits of beef cattle. J. Anim. Sci. 24:21-28.

Gregory, K. E., L. A., Swiger, R. M. Koch, L. J. Sumption, J. E. Ingalls, W. W. Rowden, and J. A. Rothlisberger. 1966a. Heterosis effects on growth rate of beef heifers. J. Anim. Sci. 25:290-298.

Gregory, K. E., L. A., Swiger, L. J. Sumption, R. M. Koch, J. E. Ingalls, W. W. Rowden, and J. A. Rothlisberger. 1966b. Heterosis effects on growth rate and feed efficiency of beef steers. J. Anim. Sci. 25:299-310.

Gregory, K. E., L. A., Swiger, L. J. Sumption, R. M. Koch, J. E. Ingalls, W. W. Rowden, and J. A. Rothlisberger. 1966c. Heterosis effects on carcass traits of beef steers. J. Anim. Sci. 25:311-322.

Gregory, K. E., L. V. Cundiff, R. M. Koch, D. B. Laster, and G. M. Smith. 1978. Heterosis and breed maternal and transmitted effects in beef cattle. I. Preweaning traits. J. Anim. Sci. 47:1031-1041.

Gregory, K. E. and L. V. Cundiff. 1980. Crossbreeding in beef cattle: Evaluation of systems. J. Anim. Sci. 51:1224-1242.

Gregory, K. E., L. V. Cundiff, and R. M. Koch. 1991. Breed effects and heterosis in advanced generations of composite populations for preweaning traits of beef cattle. J. Anim. Sci. 69:947-960.

Gregory, K. E., L. V. Cundiff, and R. M. Koch. 1999. Composite breeds to use heterosis and breed differences to improve efficiency of beef production. USDA Tech. Bull. 1875.

Hammack, S. P. 2003. Cattle types and breeds. Texas Adapted Genetic Strategies. E-190. Texas Cooperative Extension, Texas A&M Univ. System.

Hedrick, H. B., J. F. Lasley, J. P. Jain, G. F. Krause, B. Sibbit, L. Langford, J. E. Comfort, and A. J. Dyer. 1970. Quantitative carcass characteristics of reciprocally crossed Angus, Charolais, and Hereford heifers. J. Anim. Sci. 31:633-641.

Key, K.L. 2004. Heterosis and heterosis retention for reproductive and maternal traits in Brahman-British crossbred cows. Ph.D. Diss., Texas A&M University, College Station.

Klosterman, E. W., V. R. Cahill, and C. F. Parker. 1968. A comparison of the Hereford and Charolais breeds and their crosses under two systems of management. Ohio Agric. Res. and Dev. Center Res. Bull. 1011:2-21.

Koger, M., F. M. Peacock, W. G. Kirk, and J. R. Crockett. 1975. Heterosis effects on weaning performance of Brahman-Shorthorn calves. J. Anim. Sci. 40:826-833.

Koger, M. 1980. Effective crossbreeding systems utilizing Zebu cattle. J. Anim. Sci. 50:1215-1220.

Lasley, J. F., G. F. Krause, J. P. Jain, H. B. Hedrick, B. Sibbit, L. Langford, J. E. Comfort, and A. J. Dyer. 1971. Carcass quality characteristics in heifers of reciprocal crosses of the Angus, Charolais, and Hereford breeds. J. Anim. Sci. 32:406-412.

Long, C. R., and K. E. Gregory. 1974. Heterosis and bred effects in preweaning traits of Angus, Hereford and reciprocal cross calves. J. Anim. Sci. 39:11-17.

Long, C. R. 1980. Crossbreeding for beef production: Experimental results. J. Anim. Sci. 51:1197-1223.

Mackinnon, M. J., D. J. S. Hetzel, and J. F. Taylor. 1989. Genetic and environmental effects on the fertility of beef cattle in a tropical environment. Austr. J. Agric. Res. 40:1085-1097.

Mangus, W. L., and J. S. Brinks. 1971. Relationships between direct and maternal effects on growth in Herefords: I. Environmental factors during preweaning growth. J. Anim. Sci. 32:17-25.

Marshall, D. A., W. R. Parker, and C. A. Dinkel. 1976. Factors affecting efficiency to weaning in Angus, Charolais and reciprocal cross cows. J. Anim. Sci. 43:1176-1187.

McCarter, M. N., D. S. Buchanan, and R. R. Frahm. 1991. Comparison of crossbred cows containing various proportions of Brahman in spring or fall calving systems: III. Productivity as three-, four-, and five-year olds. J. Anim. Sci. 69:2754-2761.

McDonald, R. P., and J. W. Turner. 1972. Estimation of maternal heterosis in preweaning traits of beef cattle. J. Anim. Sci. 35:1146-1154.

N.R.C. 1996. Nutrient Requirements of Beef Cattle, Seventh Revised Ed. National Academy Press, Washington, D.C.

Newman, S., M. D. MacNeil, W. L. Reynolds, B. W. Knapp, and J. J. Urick. 1993. Fixed effects in the formation of a composite line of beef cattle. I. Experimental design and reproductive performance. J. Anim. Sci. 71:2026-2032.

Oklahoma State University Website. Breeds of Livestock-Cattle Breeds. Available: http://www.ansi.okstate.edu/breeds/cattle. Accessed August 18, 2006.

Olson, T. A., F. M. Peacock, and M. Koger. 1993. Reproductive and maternal performance of rotational, three-breed, and *inter se* crossbred cows in Florida. 1993. J. Anim. Sci. 71:2322-2329.

Pahnish, O. F., J. S. Brinks, J. J. Urick, B. W. Knapp, and T. M. Riley. 1969. Results from crossing beef x beef and beef x dairy breeds: Calf performance to weaning. J. Anim. Sci. 28:291-299.

Peacock, F. M., M. Koger, W. G. Kirk, E. M. Hodges, and A. C. Warnick. 1971. Reproduction in Brahman, Shorthorn and crossbred cows on difference pasture programs. J. Anim. Sci. 33:458-465.

Peacock, F. M., M. Koger, T. A. Olson and J. R. Crockett. 1981. Additive genetic and heterosis effects in crosses among cattle breeds of British, European, and Zebu origin. J. Anim. Sci. 52:1007-1013.

Rendel, J. M. 1980. Low calving rates in Brahman cross cattle. Theor. Appl. Genet. 58:207-210.

Riley, D.G., J.O. Sanders, R.E. Knutson, and D.K. Lunt. 2001. Comparison of F_1 *Bos indicus* x Hereford cows in central Texas: I. Reproductive, maternal, and size traits. J. Anim. Sci. 79:1431-1438.

Roberson, R. L., J. O. Sanders, and T. C. Cartwright. 1986. Direct and maternal genetic effects on preweaning characters of Brahman, Hereford and Brahman-Hereford crossbred cattle. J. Anim. Sci. 63:438-446.

Sagebiel, J. A., G. F. Krause, B. Sibbit, L. Langford, J. E. Comfort, A. J. Dyer, and J. F. Lasley. 1969. Dystocia in reciprocally crossed Angus, Hereford and Charolais cattle. J. Anim. Sci. 29:245-250.

Sanders, J. O. 1980. History and development of Zebu cattle in the United States. J. Anim. Sci. 50:1188-1200.

SAS. 1990. SAS User's Guide: Statistics. SAS Institute, Inc., Cary, North Carolina.

Seebeck, R. M. 1973. Sources of variation in the fertility of a herd of Zebu, British, and Zebu x British cattle in Northern Australia. J. Agric. Sci., U. K. 81:253-262.

Seifert, G. W., and J. F. Kennedy. 1972. A comparison of British breed crosses with F_1 and F_2 Zebu x British cattle on the basis of a productivity index. Proc. Aust. Soc. Anim. Prod. 9:143-146.

Turner, J. W., B. R. Farthing, and G. L. Robinson. 1968. Heterosis in reproductive performance of beef cows. J. Anim. Sci. 27:336-338.

Turner, J. W., and R. P. McDonald. 1969. Mating-type comparisons among crossbred beef cattle for preweaning traits. J. Anim. Sci. 29:389-397.

Turner, H. A., G. B. Thompson and J. L. Clark. 1974. Cow size as related to energetic efficiency. J. Anim. Sci. 39:256 (Abstr).

Turner, J. W. 1980. Genetic and biological aspects of Zebu adaptability. J. Anim. Sci. 50:1201-1205.

Urick, J. J., B. W. Knapp, R. L. Hiner, O. F. Pahnish, J. S. Brinks, and R. L. Blackwell. 1974. Results from crossing beef x beef and beef x brown swiss: Carcass quantity and quality traits. J. Anim. Sci. 39:292-302.

USDA. National Agricultural Statistics Service. 2005. Available: http://www.usda.gov/nass/pubs/agr05/acro05.htm. Accessed August 18, 2006.

Willham, R. L. 1970. Genetic consequences of crossbreeding. J. Anim. Sci. 30:690-693.

Willham, R. L. 1972. The role of maternal effects in animal breeding: III. Biometrical aspects of maternal effects in animals. J. Anim. Sci. 35:1288-1293.

Willham, R. L. 1974. Beef-dairy crossbreeding. Proc. Working Symp. On Breed Evaluation and Crossing Experiments. Zeist, The Netherlands. 245-259.

Wiltbank, J. N., K. E. Gregory, L. A. Swiger, J. E. Ingalls, J. A. Rothlisberger, and R. M. Koch. 1966. Effects of heterosis on age and weight at puberty in beef heifers. J. Anim. Sci. 25:744-751.

Wiltbank, J. N., K. E. Gregory, J. A. Rothlisberger, J. E. Ingalls, and C. W. Kasson. 1967. Fertility in beef cows bred to produce straightbred and crossbred calves. J. Anim. Sci. 26:1005-1010.

APPENDIX

Table A. Weaning weight, 18-month weight, 30-month weight, age of dam, and reproductive history of individual cows

							Repro History[a]							
Birth Year	**Breed**	**Dam ID**	**DOD Age**	**WWT**	**18 mo wt**	**30 mo wt**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
96	F2HB	055F	2	454	718	768	1	1	1	1	1	1	1	0
		234F	2	398	700	1032	0	1	1	1	1	1		
		269F	5	528	732	1004	0	1	0					
	HBBH	063F	2	486	772	844	1	1	1	1	1	1	1	1
		071F	2	458	782	838	1	1	1	1	1	1	1	1
		342F	5	404	604	932	0	0						
		387F	2	388	680	758	1	1	1	1	1	1	1	1
		844F	2	382	648	1002	0	0						
		846F	2	362	676	1046	0	1	0	1				
		847F	2	318	594	864	0	1						
		849F	2	258	502	.	0							
		875F	2	304	628	984	0	0						
97	F2HB	014G	6	600	984	1012	1	0						
		015G	6	498	844	774	1	0	1	1	1	1	0	
		198G	6	430	694	708	1	0						
		255G	6	454	862	968	1	1	1	1				
	F2BH	008G	3	564	936	974	1	0	1	0				
		032G	3	484	862	1558	0							
		266G	3	500	838	1142	0	0	1					
		267G	3	428	760	986	0	1	0					
		268G	3	450	814	918	0	1	1	1	1	1	1	
		270G	3	532	956	1004	1	1	0	1	0			
		274G	3	426	798	844	1							
		304G	2	474	884	1124	0	0						
		312G	3	418	760	1044	0	1	1	1	1	1	1	
		401G	2	406	816	1012	0	1	0					
		408G	3	500	956	1376	0							
		496G	3	482	838	1128	0	1	0					
		498G	3	382	780	1154	0							
		501G	2	376	836	1158	0	1	0					
		773G	2	326	776	1156	0	0						
	BHHB	031G	3	588	1004	1146	1	0	1	1	1	1	0	
		442G	3	448	838	1132	0	0						
		731G	3	366	788	.	0							

Table A Continued

							Repro History[a]							
Birth Year	**Breed**	**Dam ID**	**DOD Age**	**WWT**	**18 mo wt**	**30 mo wt**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
97	HBBH	053G	5	514	796	864	1	0						
		059G	5	492	762	784	1	0						
		190G	4	448	756	768	1	0						
		191G	5	492	814	854	1	0	1	1	1			
		208G	4	462	816	1154	0							
		252G	5	578	896	936	1	0	1	1	1	0		
		317G	5	432	756	814	1	0						
		321G	4	500	854	966	1	1	1	1	1	1	1	
		420G	5	494	778	818	1	0	1	1	1	0		
		487G	5	468	758	834	1	0						
98	F2BH	047H	3	482	808	.								
		100H	3	538	984	.								
		112H	3	538	938	820	1	0	1	0	1	1		
		158H	4	520	906	.								
		159H	4	556	874	.	0							
		165H	3	454	896	785	1	0	1	0				
		439H	4	554	978	1125	0	1	0					
		882H	3	448	934	.								
	BHHB	111H	7	566	918	785	1	0	1	1	0			
		220H	4	540	1016	904	1	0	1	1	1	0		
		269H	4	542	862	970	0	0						
		273H	7	438	748	805	0	0						
		274H	7	566	962	1025	0	1	0					
		438H	4	510	926	1015	0	1	1	1	1	1		
		503H	2	434	752	638	1	0	1	1	1	0		
		541H	4	546	1028	995	1	1	1	1	1	1		
		744H	4	476	842	675	1	0	1	1	0			
		745H	9	456	764	660	1	0	1	1	1	1		
99	F2HB	067J	8	466	782	780	1	1	1	1	1			
		129J	5	516	875	930	1	1	1	1	1			
		130J	5	534	905	940	1	1	1	1	0			
		188J	5	532	910	780	1	0	1	1	1			
		269J	5	458	820	860	1	0	1	1	1			
		334J	5	508	930	920	1	0	1	1	1			
		524J	5	482	808	.								
		598J	5	536	978	985	1	1	1	1	1			

Table A Continued

							Repro History[a]							
Birth Year	**Breed**	**Dam ID**	**DOD Age**	**WWT**	**18 mo wt**	**30 mo wt**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
99	HBBH	158J	4	474	845	1260	1	1	0	1	1			
		191J	5	562	870	1040	1	1	1	1	1			
		223J	4	508	848	830	1	1	1	1	1			
		270J	4	492	792	830	1	1	1	1	1			
		803J	9	426	768	.								

[a]The number 1 indicates a calf weaned; 0 indicates a failure to wean a calf

Table B. Weights and conditions scores with reproductive record through 4-years-of-age

Birth Year	Breed	Dam ID	WWT	18 mo wt	18 mo CS	2 yr Repro[a]	30 mo wt	30 mo CS	3 yr Repro[a]	42 mo wt	42 mo CS	4 yr Repro[a]
96	F2HB	055F	454	718	5	1	768	5	1	922	5	1
		234F	398	700	5	0	1032	6	1	1002	4	1
		269F	528	732	4	0	1004	6	1	1006	3	0
	HBBH	063F	486	772	6	1	844	4	1	982	5	1
		071F	458	782	5	1	838	4	1	910	4	1
		342F	404	604	5	0	932	6	0.5	.	.	.
		387F	388	680	5	1	758	5	1	866	4	1
		844F	382	648	5	0	1002	6	0	.	.	.
		846F	362	676	5	0	1046	7	1	978	4	0
		847F	318	594	5	0	864	6	1	872	5	.
		849F	258	502	5	0	.	.	.	.	.	.
		875F	304	628	5	0	984	6	0.5	1202	6	PB
97	F2HB	014G	600	984	6	1	1012	4	0	.	.	.
		015G	498	844	6	1	774	4	0	1035	6	1
		198G	430	694	6	1	708	4	0	.	.	.
		255G	454	862	6	1	968	5	1	1050	6	1
	F2BH	008G	564	936	5	1	974	5	0	1255	6	1
		032G	484	862	5	0	1558	6	PB	.	.	.
		266G	500	838	5	0	1142	5	0	1310	6	1
		267G	428	760	6	0.5	986	5	1	962	4	0
		268G	450	814	6	0.5	918	6	1	895	5	1
		270G	532	956	6	1	1004	5	1	1030	5	0
		274G	426	798	7	1	844	5	PB	.	.	.
		304G	474	884	5	0.5	1124	6	0	.	.	.
		312G	418	760	6	0	1044	7	1	1050	6	1
		401G	406	816	6	0	1012	6	1	925	4	0

Table B. Continued.

Birth Year	Breed	Dam ID	WWT	18 mo wt	18 mo CS	2 yr Repro[a]	30 mo wt	30 mo CS	3 yr Repro[a]	42 mo wt	42 mo CS	4 yr Repro[a]
97	F2BH	408G	500	956	5	0	1376	6	PB	.	.	.
		496G	482	838	5	0	1128	6	1	980	5	0
		498G	382	780	5	0	1154	6	PB	.	.	.
		501G	376	836	5	0	1158	6	1	1060	5	0
		773G	326	776	5	0	1156	6	0.5	.	.	.
	BHHB	031G	588	1004	6	1	1146	4	0	1400	6	1
		442G	448	838	6	0	1132	7	0.5	.	.	.
		731G	366	788	5	0.5	.	.	.	.	.	.
	HBBH	053G	514	796	6	1	864	5	0	.	.	.
		059G	492	762	6	1	784	4	0	.	.	.
		190G	448	756	6	1	768	4	0	.	.	.
		191G	492	814	5	1	854	4	0	1145	6	1
		208G	462	816	6	0	1154	6	PB	.	.	.
		252G	578	896	5	1	936	4	0	1150	6	1
		317G	432	756	5	1	814	5	0	.	.	.
		321G	500	854	6	1	966	5	1	990	5	1
		420G	494	778	6	1	818	4	0	1040	6	1
		487G	468	758	5	1	834	3	0	.	.	.
98	F2BH	047H	482	808	5	PB	.	.	.	.	.	.
		100H	538	984	5	PB	.	.	.	.	.	.
		112H	538	938	5	1	820	4	0	1140	6	1
		158H	520	906	5	PB	.	.	.	.	.	.
		159H	556	874	5	0	.	.	.	.	.	.
		165H	454	896	5	1	785	4	0	1060	5	1
		439H	554	978	6	0	1125	5	1	980	4	0
		882H	448	934	5	PB	.	.	.	.	.	.

Table B. Continued

Birth Year	Breed	Cow ID	WWT	18 mo wt	18 mo CS	2 yr Repro[a]	30 mo wt	30 mo CS	3 yr Repro[a]	42 mo wt	42 mo CS	4 yr Repro[a]
98	BH x HB	111H	566	918	5	1	785	4	0	1020	5	1
		220H	540	1016	5	1	904	4	0	1220	6	1
		269H	542	862	5	0	970	.	0	.	.	.
		273H	438	748	5	0	805	.	0	.	.	.
		274H	566	962	5	0	1025	5	1	940	4	0
		438H	510	926	5	0	1015	6	1	940	5	1
		503H	434	752	5	1	638	4	0	890	5	1
		541H	546	1028	6	1	995	5	1	1120	5	1
		744H	476	842	6	1	675	4	0	950	5	1
		745H	456	764	6	1	660	4	0	950	5	1
99	F_2 HB	067J	466	782	6	1	780	5	1	990	5	1
		129J	516	875	6	1	930	4	1	1145	6	1
		130J	534	905	5	1	940	4	1	1160	5	1
		188J	532	910	5	1	780	3	0	1430	6	1
		269J	458	820	5	1	860	4	0.5	1195	6	1
		334J	508	930	6	1	920	4	0	1360	6	1
		524J	482	808	5	.	.	.	.	.	.	.
		598J	536	978	6	1	985	4	1	1250	5	1
	HB x BH	158J	474	845	6	1	1260	4	1	1075	5	0.5
		191J	562	870	5	1	1040	4	1	1260	6	1
		223J	508	848	6	1	830	5	1	1085	5	1
		270J	492	792	5	1	830	4	1	966	5	1
		803J	426	768	5	.	.	.	.	.	.	.

[a]1 designates a calf weaned, 0.5 designates a calf born but not weaned, 0 designates a failure to have a calf, and PB designates a cow that was palpated bred before she was sold and was not given the opportunity to calve

Table C. Unadjusted averages of 18-month weight and condition score by birth year and breed of cow

Birth Year	Breed	Avg 18 mo wt	Avg 18 mo CS[a]
96	F2HB	716.7	4.7
	HBBH	654.0	5.1
97	F2HB	846.0	6.0
	F2BH	840.7	5.5
	BHHB	876.7	5.7
	HBBH	798.6	5.6
98	F2BH	914.8	5.1
	BHHB	881.8	5.3
99	F2HB	876.0	5.5
	HBBH	824.6	5.4
96	-	669.7	5.0
97	-	831.6	5.6
98	-	896.4	5.2
99	-	856.2	5.5
-	F2HB	836.1	5.5
-	F2BH	866.4	5.3
-	BHHB	880.6	5.4
-	HBBH	749.8	5.4

[a]Condition score on a 1-9 scale

VITA

Name: Bradley Allen Wright

Address: 2471 TAMU
College Station, TX 77843

Email Address: wrightbrad99@hotmail.com

Education: B.S., Genetics and Animal Science, Texas A&M University, 2003
M.S., Animal Breeding, Texas A&M University, 2006